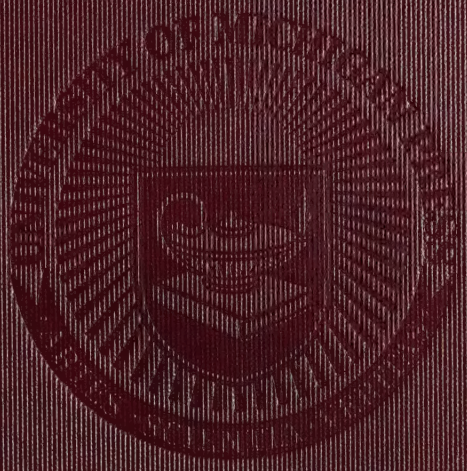
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MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

EDITORS

EUGENE S. McCARTNEY
UNIVERSITY OF MICHIGAN

ALFRED H. STOCKARD
UNIVERSITY OF MICHIGAN

VOLUME XXIII

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quod quaerat omnis mundus habeat."
— SENECA, *Naturales Quaestiones*

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JAR BURIALS IN THE BABUYAN GROUP, PHILIPPINE ISLANDS, ESPECIALLY THOSE OF DALUPIRI ISLAND

HARLEY HARRIS BARTLETT

JAR BURIALS ON CAMIGUIN ISLAND

DURING 1911 Merton L. Miller,[1] of the Philippine Bureau of Ethnology, published an article on the burial mounds of Camiguin Island in the Babuyan group, based upon a trip of archaeological investigation which he made in April, 1910. His interest in the island seems to have been inspired by Captain Mitchell, of the Signal Corps of the U. S. Army, who, in 1909, had opened two or three "stone piles" on Camiguin and had found a large earthenware jar in the center of each.

Miller investigated burials on the volcano known as Dakelabalai, at the southeastern point of the island. Especially on the southwestern slope there were several bare places of ten to twenty hectares in area with fumaroles, and on or near these fumarole areas the burial "mounds" were found. He saw some "mounds" on the northeastern slope of the volcano also, but others that were reported to him proved to be natural rock outcrops. He believed, however, that there were other burial places that he did not see.

At the time of Miller's visit there were only about ninety persons on Camiguin, recent immigrants, mostly Ilocanos. It was reported to him that twenty or thirty years before a population of several thousand had died of cholera, but he found on the forested island no clearings where such an extensive population could have lived. If clearings had existed, they had been obliterated by secondary brush or forest. No old local stock among the people was detected, although some of them had been born on Camiguin. One point in Miller's article, which he does not stress at all, indicates that there may be even yet some trace of true Babuyan blood on the island. (The

[1] Miller, Merton L., "The Burial Mounds of Camiguin Island," *Phil. Journ. Sci.*, D6: 1–5, Pls. I–V. 1911.

migration of the Babuyanos to Luzon in the years from 1690 to 1745 is discussed below.) According to Miller, a young man said that he had heard from an old man that they formerly buried the dead in earthenware vessels, cutting the legs of the corpse at the knees so as to make it possible, by doubling the legs, to put the entire body into a jar. This may be a real tradition, but may on the contrary be merely a supposition of some intelligent immigrant.

Miller discovered a number of very interesting facts. The jars were of two kinds: those big enough, when covered with an inverted one of the same sort for a lid, to receive an adult body in a squatting posture; and others too small to have served as receptacles for anything but bones. The largest were sixty centimeters in diameter and eighty tall; the smallest twenty centimeters in diameter and twenty tall. Those that he interpreted as receptacles only for bones had openings not more than fifteen centimeters in diameter, i.e. too small to receive an unbroken skull or the body of even a young child. Lids were of two kinds, some being merely larger jars of the same sort, whereas "others seemed to have covered the opening of the vessel and to have extended but a short distance beyond the edges."

Although Miller stated: "There can be no doubt that these jars were used for containing the bones of the dead," he found the merest unidentifiable fragments of bone in two jars and a small piece of a skull bone in a third. In two jars were "a few common, pale blue glass beads" and "a piece of dark brown loosely woven, coarse fabric," which fell to pieces at a touch. He intimated that "a black sticky mass" in one jar, "which had a very unpleasant odor" showed that a corpse had decomposed in the jar. One doubtless had, but my own experience would lead me to believe that the odor was not that of the ancient corpse, but merely hydrogen sulphide derived from sulphates by the reducing action of humus, currently produced by the decay of plant roots, dead land snails, crabs, and what not.

Miller's conclusion is that two modes of disposing of the dead might have been followed at the same time, namely, that of placing the entire body in a jar and that of placing the bones only in a smaller jar after the flesh had been removed or had decayed.

A recent reminiscent account of the excavation of burial places on the Island of Camiguin by Captain Fred D. Burdett [2] gives cer-

[2] Burdett, F. D., "Camiguin Island — Home of a Lost Race," *Philippine Magazine*, 33: 28–29, 34–36. 1936.

tain information that is apparently intended to be reliable, since it repeats in large part an article which he contributed to *Man* in 1927.[3] He went to Camiguin in a little thirty-foot native boat with a crew of Ilocanos, at the suggestion of Henry Gardiner Ferguson of the Philippine Bureau of Mines, who had told him that there were "literally thousands of burial mounds of a long lost race scattered all over the island, so that at one time it must have been very thickly populated. Their descendants were evidently annihilated in some great volcanic eruption which destroyed every living thing on the island, possibly centuries ago. The only living people on the island are a few Ilocanos or Cagayanos . . . ." The foregoing passage, although written as a direct quotation, need not be supposed to represent Ferguson's ideas with entire fidelity. Ferguson is said by Burdett to have been marooned on Camiguin for three months.

Without placing implicit faith in the more lurid details of Burdett's articles, one must credit part of what he has to say. He crossed the island from west to east in order to visit a crater in a volcanic ash bed where there was a great deposit of sulphur. "On the opposite side were three ridges running down to where we were standing and as a gust of wind blew the steam away, I noticed that they were covered with stone cairns. Large cairns dotted the two outer ridges but the middle one was covered with smaller ones. It was, we later discovered, an ancient burial ground — for men on one ridge, women on another, and children in the middle. Some of these cairns had been covered with masses of almost solid sulphur. I could not help thinking what a value the Smithsonian Institution or some other great museum would put on these extraordinary looking cairns. On opening one of them later on, I found the large urns and the bodies they had contained had been displaced by pure, crystalline sulphur in its most beautiful form. . . . The men's cairns were some eight feet in diameter, the inner part being earth mixed with small stones enclosing urns about four feet high, while the outside was a wall of rock built round to hold the mass together . . . ."

The foregoing quotation is from Burdett's later and presumably less careful article. The earlier article explains why he concluded that the three ridges were used respectively for the burial of men,

[3] Burdett, F. D., "A Note on the Discovery of Burials in the Volcanic Craters of Camiguin Island off the Coast of Northern Luzon," *Man*, 27 : 174–176. 1927.

children, and women: "The three ridges running down into the solfataras we found contained three different classes of urns. The eastern were all big cairns, and contained big urns evidently for adult men, which we verified later in two instances where the urns were not transformed into glowing sulphur. The western one contained smaller urns, which were evidently those of women; the center ridge contained only little wee urns and was evidently the children's cemetery."

I shall now quote again from the more recent article: "While my companions, apparently without any fear of the numerous crocodiles were day after day fishing . . . I continued to explore the island and found it literally riddled with crater holes, but none were really active and nearly all were what are known as dying volcanoes. In every one or in the immediate vicinity were scores of the burial cairns, possibly of great antiquity, while high up above the volcanoes slumbering below were great grave yards of thousands of cairns. One urn I found was evidently of Chinese origin, as there was a great dragon running around the outside of the urn, and jade beads were found in others; relics possibly of a very ancient civilization. As regards walls of houses or ruins of any kind, not a trace; only the stone walls of the burial cairns were left, and I have no doubt that there are scores of grave yards elsewhere buried underneath the great deposits of volcanic ash that cover so much of present-day Camiguin."

In the earlier article, in *Man*, Burdett gave practically the same information, but was more guarded in that he said the beads found with the jar burials were "apparently of jade" and that the one exceptional jar which was not of poor native-made pottery "was undoubtedly of Chinese, or Japanese, origin, as it had a dragon drawn on the outside of it." He also adds some details about the human bones, which (to the present writer) seem quite fanciful. He says: "We found, later, bones of exceptionally large size in several outlying places, the skulls very retreating, the jaws prognathous; the humerus bones were exceptionally long, very like the gorilla's, while the femurs were correspondingly short, and the teeth were perfect and rounded so much that the incisors could hardly be recognized; the teeth had the appearance of people who had lived on a purely vegetable and fruit diet."

Although Burdett refers to the jar burials as the "sole evidence of a long lost race," a race which he would evidently have his readers

conclude to be physically distinctly anthropoid, his mention of Li Ma Hong's visit to Camiguin for sulphur is extremely suggestive, for it indicates the possibility that there may have been direct Chinese influence there long before that great pirate's day. The supposed resemblance of the bones to those of the gorilla smacks too much of Sunday newspaper science, and, lacking verification, must be dismissed as incredible. It is unfortunate indeed that accidental destruction was the immediate fate of "two sets of urns in perfect condition, with the skeletons in them intact" which, according to Burdett, he succeeded in getting to the Manila Museum by considerable work and after much anxiety and expense, only to have them destroyed by the clumsiness of some workmen.

OTHER REFERENCES TO JAR BURIAL IN THE BABUYANES

Camiguin Island is the most southeasterly of the Babuyan group. To the west is Fuga, for which I find only one reference to jar burials, and that one, unfortunately, giving no first-hand information. Willcox, the author of one of the most informative and valuable travel books on Luzon,[4] referring to a trip by boat from Aparri to Manila, has this to say: "Our journey . . . did not, much to my disappointment, include the side trip sometimes made to the Babuyanes Islands for cattle. One of these islands, Fuga, is especially interesting; urn-burial prevailed in it in the past, the urns in some cases being arranged in a circle around a central urn or altar. Moreover, there is in Fuga a stone building known as the Castle, with arched doorways, said not to be of Spanish origin, and near by is a plain strewn with human skulls and other bones, probably the scene of a battle. The skulls are remarkable from their great size, some of them being reported as extraordinary in this respect." Here we probably have, intermingled with fable, some substantially valuable clues, indicating that Fuga, and indeed the whole group of islands, should be carefully investigated by qualified archaeologists.

To the north and a little to the west of Fuga is Dalupiri, where I made the observations recorded in this article. In line with Dalupiri, extending northeastward, are Calayan (Kalayan) and Babuyan Claro. There seems to be no information regarding Babuyan Claro.

[4] Willcox, Cornélis De Witt, *The Head Hunters of Northern Luzon. From Ifugao to Kalinga: a Ride through the Mountains of Northern Luzon* (Kansas City, Mo.: Franklin Hudson Publishing Co., 1912), pp. 256–257.

The ancient burial mounds of Calayan Island, according to an article by Inocencio B. Maddela,[5] are locally called *kunukun*, and are ascribed to the "Tirong," Moro pirates of whom stories are still told on the island. Legend has it that some of the Tirong gave up piracy and settled among the people of the island, taking Christian wives, but since they were not converted to the Catholic faith the *cura* would not let their dead be buried in consecrated ground. The Tirong therefore built the *kunukun* along the shore. This legend must certainly confuse the truly ancient islanders with very late comers, for the Tirong are probably correctly identified by Maddela with the Tirones of Philippine history, who were (perhaps unwillingly) allies of the Joloano pirates. The latter were the terror of Philippine seas and coastal towns for three hundred years, but the particular Tirones who may have reached the Babuyan Islands must have come later than 1749 if the legend is correct that they were sent by Sultan Bantilan to harass the North after he usurped the throne of Sulu during the historic visit of his brother Sultan Ali Muddin to Manila. Clearly the settlement of a few small boat loads of pirates at so late a date can be only a fictive explanation of the abundant remains of an ancient culture on the Babuyanes. There is nothing to suggest Muhamadan burial in the construction of the *kunukun*, nor do the few beads which are the certainly reported artifacts of these Calayan graves indicate a recent Muhamadan culture.

In my opinion we may definitely identify the Tirong or Tirones with the present Tidong of the east coast of Borneo. The latter were mentioned as long ago as 1779 by Captain Forrest,[6] whose account of them is quoted by H. Ling Roth [7] as follows: "On the N. E. part of Borneo is a savage piratical people called Oran Tedong, or Tiroon, who live far up certain rivers. The Sooloos have lately subdued them by getting the Rajah (or chief) into their power. These Oran Tedong fit out vessels large and small, and cruise among the Philippine Islands, as has been formerly said. They also cruise

[5] Maddela, Inocencio B., "The Tirong, Ancient People of the Babuyan Islands," *Phil. Mag.*, 34 : 18 19, 139. 1937. This article was received after the meeting at which the present paper was read.

[6] Forrest, Thomas, *A Voyage to New Guinea and the Moluccas, from Balambangan.* London: J. Robson, 1779.

[7] Roth, H. Ling, *The Natives of Sarawak and British North Borneo*, 2 vols. (New York: Truslove and Comba, 1896), I : 35–36.

from their own country, west to Pirate's Point, and down the coast of Borneo, as far as the island of Labuan . . . . The Oran Tedong live very hard on their cruises, their provisions sometimes being raw sago flour. They have not *attop* or [boat] covering; nay, sometimes, as the Sooloos have told me, they go, especially if it rains, stark naked. The Moors of Magindano and the Illanos, also Moors, despise these people. When they meet, however, in roads and harbors among the Philippines, where the common prey is, they do not molest one another." There is an excellent modern account of the Tidong, who still live on the east coast of Borneo and who are given a pretty good character by the official who knew them best.[8] Taking account of the peculiarities of Captain Forrest's English spelling we may change his Oran Tedong or Tiroon to Orang Tidung or Tirung, for *oo*, of course, merely represents *u*, and his spelling of *orang* (Malay and Tidung for "man") shows that his final *n* may be rendered as *ng*. His spelling Tirun is in conformity with the Spanish Tiron. Clearly, there need be no reasonable doubt about who the Tirung of the Calayan legends were.

Maddela's article leads me to suspect that I may have overlooked an earlier account of Calayan Island by A. E. Lilius, who, accompanied by Maddela, made excavations there in 1932. Lilius (the author of *I Sailed with Chinese Pirates*) is quoted as regarding the burial "cairns" (*kunukun*) and the jars (*ranga*) as of Chinese origin. Maddela, however, believes that the jars were made locally from red clay deposits at *sitio* Bangaan ("rice-pot place"). His article makes several other interesting points.

JAR BURIAL ON DALUPIRI ISLAND

I visited Dalupiri Island for botanical collecting from October 31 through November 5, 1935, in company with Mr. José V. Santos and Mr. Moises Kalaw of the botanical staff of the University of the Philippines. We unfortunately failed to visit the topmost area on the island, where archaeological remains are said to be most abundant, but did spend part of a day in getting what information we could about the burial places that are to be seen near the mouth and along the sides of the cañon called "Manolong." On July 17 I had had an opportunity to see the island from the air, during the course

[8] Beech, Mervyn W. H., *The Tidong Dialects of Borneo.* Oxford: Clarendon Press, 1908.

of a flight made by Major-General Parker and Vice-Governor J. R. Hayden for the purpose of locating landing fields in the rough and difficultly accessible islands north of Luzon. In bird's-eye view the island is low on the east, gradually sloping upward to an elevation of perhaps a thousand feet at the highest point, and breaking away abruptly by a steep declivity to the sea on the west. It is greatly overgrazed and has open range or brushy second-growth forest over most of the surface, except in deep cañons or ravines which traverse the island from west to east. These ravines, of which Manolong is one, contain some luxuriant and relatively original vegetation, in which a good many interesting species persist in spite of the long period during which the island has been inhabited.

Manolong ravine arises on the plateau just eleven paces from the western escarpment, from which it leads directly away. The island appears to have been, prior to the elevating by faulting, a relatively low and sandy one (the original surface is sandy, underlain by consolidated clays, sandy claystone and sandstone) and to have been elevated along a fault, parallel with the western shore, which sheared the Pleistocene coral reef in two and elevated part of it to the position that it now occupies along the western rim of the escarpment. Consequently one climbs up the steep western face of the island to what was the shore line in relatively recent geological time and then walks down a gentle slope which was then the upward slope to the top of the island. The direction of westward-flowing drainage was reversed, so that in a very few years the gully which is the beginning of Manolong ravine will touch the western edge of the plateau. The old residual soils are red. The present area of the island is greater than it was at the time of the Pleistocene elevation, for considerable areas of the eastern part are covered with elevated coral, and there is coral along the western escarpment as well. Some of the coral blocks along the western edge of the old soil area were probably broken from the reef and, prior to the upfaulting of the old shore line, were rolled by surf to the place where they still lie.

The lower courses of the ravines on Dalupiri have running water. The surface of the island is so pervious that (as far as we saw) there is neither swamp nor standing water. Consequently the permanent population is on the eastern side (at the village of Visita), although there was formerly a house on the western side, where interisland boats occasionally come to load livestock.

Even on the eastern side of the island there has been some elevation. South of Visita at the mouth of Manolong ravine the cliffs are picturesque and rough. The elevated coral has been weathered, so that it is covered with thin blades, spines, and spicules that crunch underfoot and cut shoes to tatters. There are clefts, fissures, and crevasses that open laterally into Manolong ravine or directly through the sea cliff. These, of course, had their origin in such tidal races as those through which water rushes back to sea after the breakers roll in over the present coral reefs.

A high point on the edge of the sea cliff had been walled up, presumably at some ancient time, to serve as a lookout station. Strangers coming from the sea would naturally land at the outlet of the little creek in Manolong ravine, in order to get fresh water. This fortified site (see Pl. I, Fig. 1) gave a view all along the coast and was only a few paces from the cañon, into which watchers could escape unseen to warn an inland village. Inside the wall was a thick deposit of fragments of coarse pottery and sea shells, on the surface of which I found one shard of old underglaze blue Chinese porcelain.

With one other dubious exception (a bit of wall at the edge of the cañon, which had no other obvious utility than to serve as a lookout station), the remaining structures all appeared to be graves.

The latter follow a definite style of construction and are quite numerous along the open country near the rim of the cañon. Some had been badly demolished, but others were reasonably well preserved. Each consisted of a circular enclosure from eight to fifteen feet in diameter, the wall being of rough coral rock, laid without any great care in fitting and without mortar, and originally about four feet high (see Pl. II). In the center the jar was sunk about to the rim in the earth (see Pls. III–IV). At the time of burial a second inverted jar of the same sort fitted outside the rim of the lower one, so that the two formed a coffin sufficiently large to take a body in a squatting posture if the knees were doubled up under the chin. Radiating toward the overlap of the jars, and actually touching them, were several large heavy stones, between and over which were tightly chinked many small stones, forming a pavement at the center of which the upper inverted jar must have been exposed. This, being unprotected, has, in every example seen, been broken by stones being thrown upon it. The lower jars, even if cracked, are quite likely to be sufficiently intact to hold rain water, and to be filled with

a black, fetid, decomposing mass of extraneous organic matter and soil. The odor is largely that of hydrogen sulphide, and is contributed to by small dead animals such as crabs and snails. (The hermit crabs that live in borrowed sea shells climb up from the shore and may be found, alive and very active, almost anywhere.) Bones have been almost entirely dissolved by the rain water and organic acids from the humus. From the one jar that I excavated carefully (it had already been rifled) every bit of heavy material was examined after washing out the black mud by suspension and decantation. I recovered only a few unrecognizable fragments of rotten bone. Thrown out of the jar by a former robber were fragments of bone and one molar tooth (Mus. Anthropol., Univ. Mich., No. 17554). There were no beads or other artifacts whatever in the lower jar, except fragments of the upper jar.

The picture left in the mind by the excavation of one grave, the more superficial examination of two, and observation of several others was that of a circular enclosure, breast high, four or five paces across, paved within by a layer of stones about a foot thick, above which, at the center of the enclosure, the upper cover jar of the vertical pottery coffin probably projected somewhat, like the hub of a wheel. The construction is fairly well indicated by the photographs shown in Plates II–III. From each of the two enclosures photographed (aside from the one fully excavated) I took the precaution of removing enough débris to ascertain that the lower burial jar was in place. There is no reason to believe the structures are not all alike.

Many if not most of the enclosures have been disturbed and are more or less broken down, but careful excavation would doubtless disclose artifacts. I urged the resident manager of the island, Dr. Manalo, to use his influence to have the graves remain unmolested, so that some competent archaeologist may sometime find out more about them. The present population cannot resist the temptation to hunt treasure, but do not dare to keep the finds, which, in their estimation, have not been worth the danger incurred in retaining them. We have heard tales of fine beads and bracelets (even gold ones!) that were thrown away because of the superstitious belief of the people that they will have bad luck if they keep old things found in the graves. There is a story that one man, now dead, became very ill after finding a great lot of fine beads, so he threw them all away. Our local guide, Cardo, said he once found a fine blue-and-white

pinggan ("plate") which he "threw," as he put it, because of fear of what the ghost might do to him. Cardo knew four boys who had found plates, but when he tried to get them for me he found that they had been "thrown" in order to avoid misfortune. There is no actual evidence that the relatively late blue-and-white articles (no older than Ming) were in association with the jar burials, and even if they were, they may have been used for offerings to the dead. Wares of all ages, including the most recent, are likely to be used for offerings at old burial places in the Malayan region.

All the jars and fragments of jars seen by me were of the crudest possible earthenware, burned imperfectly and made of clay that contained organic matter, as was indicated by the black fracture of broken pieces that often showed a carbonaceous interior, with only the surface red, buff, or grayish. The clay was probably of local origin, for there are plenty of exposures on the island of gritty clay stone as well as sandstones. The burning was doubtless done in open bonfires, in the usual Malayan way. I am inclined to discount almost 100 per cent Burdett's story of the burial jar with a dragon around the outside.

There are not a few burial enclosures along both rims of Manolong cañon. The highest point of the island is reported to be covered with graves. Large areas of Dalupiri, however, have no obvious archaeological remains. There are massive fences of loose stone near Visita, but these are presumed to date from the recent development of the island into a ranch. Maddela[9] credits the building of a rough wall on Calayan Island to the initiative of an early Spanish *cura*.

MIGRATION OF THE BABUYANOS TO LUZON

We found no people on the island who were supposed to be of old stock. The entire population of approximately three hundred persons is locally believed to be of recent origin from the Ilocos Provinces and Cagayan. It would seem incredible that there should be no descendants of the old Babuyanos, if, as fortunately they do, no historical records remained to indicate what became of them and where they presumably live to the present day. Scheerer[9a] calls

[9] As cited in note 5.

[9a] Scheerer, Otto, "Zur Ethnologie der Inselkette zwischen Luzon und Formosa," *Mitteilungen d. deutsch. Gesells. f. Natur- und Völkerkunde Ostasiens* (Tokyo, 1906), 11 : 1–31, Taf. I–VI.

attention to the historical record that the people of the Babuyanes all migrated to Luzon in the years following 1690. Indeed, as late as 1885, the language of the Babuyan Islands as well as of the town of Malaneg, Cagayan, was said by Jordana [10] to be "Malaneg." No language or dialect so named is listed by Beyer,[11] and it may have become extinct. Nevertheless, a search of the locality for dialectical peculiarities would even at this late date be very desirable. Scheerer says that the Babuyanos received their first Spanish missionary about 1686, and that about 1690, when the missionaries found life in the Babuyanes intolerable, they sought a way out of their difficulty by settling their new converts in Luzon. The king of Spain objected, and ordered the people returned to their homes, but, in spite of this order, renewed emigration took place, which, in the years from 1740 to 1745, completely depopulated the islands. So it is to be understood how the Ilocanos were able to step unhindered into the place of the departed Babuyanos. There is even a record of Christian converts from the Batanes under the Dominican priest P. Bel attempting to colonize the island of Calayan in the Babuyanes in 1720. Half of these colonists starved and the rest migrated farther, to Luzon.

Malumbres [12] quotes a letter, addressed to the provincial vicar and written from Camiguin in 1743 by the famous Fr. José Tomás Marin, which gives a graphic picture of the hardships that were endured by the clergy and civil servants in carrying out the migration of islanders from the Babuyanes and Batanes to Cagayan. Malumbres also quotes old documents stating the number of tithe payers from the Calayanes, Batanes, and Babuyanes who were transported to the pueblo of Bugay (273 tithe payers) and to the vicinity of Tagga and Totol (110 tithe payers). He tells us that Fr. Mateo Gonzales moved the islanders of Babuyan Claro to Amulung, Cagayan, and was the first priest to serve and evangelize the Batanes; that Fr. Jerónimo Ulloa was devoted to the churches in the Babuyanes; that Fr. José Tomás Marin bore the brunt of responsibility and toil in the migration of the islanders.

[10] Jordana y Morera, Ramon, *Bosqueho geográfico e histórico-natural del Archipiélago Filipino.* Madrid: Imprenta de Moreno y Rojas, 1885.

[11] Beyer, H. Otley, *Population of the Philippine Islands in 1916.* Manila: Philippine Education Co., Inc., 1917.

[12] Malumbres, Fr. Julian, *Historia de Cagayan* (Manila: Tip. Sto. Tomás, 1918), pp. 70–72, 310–312, 432–434.

ANALOGY WITH BURIAL CUSTOMS IN SOUTH CHINA

In one of the large laterally exposed pits of the elevated reef at Manolong we found a big coarse earthenware jar chinked in with rocks. It had been broken, and contained no bones, but I photographed it (see Pl. I, Fig. 2). Such jars are said to have been quite numerous in clefts and on ledges of the cliffs and steep slopes, but to have been broken by stones thrown at them. The jar seen was not large enough to have contained an adult body, but would have served for a child, or for the redisposal of exhumed bones. There is only the word of the present inhabitants to indicate that bones have been found in such jars, and of course the disintegration and solution of the skeletons by rain water and humus acids would take place rapidly as soon as the covers were destroyed. There should be no expectation of finding bones in disturbed jars, and hence no reason to suppose that the isolated jars without the elaborate stone enclosure and floor represent anything else than a simpler method of disposal of the dead, used perhaps for children or persons of lowly status.

It was this less elaborate type of jar sepulture that struck me as having a close parallel in South China. The jar photographed *in situ* (see Pl. I, Fig. 2) was of about the size and shape of those which one sees about Kowloon in the rocky places, containing bones only. In South China the bones are preserved in jars after a body has been originally buried and allowed to decay in a place of such good auspices (*fung shui*, literally, "wind and water") that it must be used over and over for burials. In thickly populated China hardly anyone is important enough to stay permanently in a very desirable grave!

Since it is not always easy to find in the literature satisfactory descriptions or illustrations of commonplace things such as every traveler sees but does not bother to write about, I venture to publish here for comparison some pictures taken at the picturesque walled village Na Chin Moy, near Kowloon, in 1919. This interesting survival of old China was demolished in the interests of modernization and sanitation in 1926–27, but Kwangtung Province doubtless has thousands of localities presenting similar scenes.

The hill that rose behind the village wall is covered (or was, in 1918) with beautiful residual boulders around each of which were arranged a group of jars with flat saucer-like lids weighted down by stones (see Pl. V). Each jar contained a skeleton, removed to this

less auspicious place after preliminary burial in a place of good omen (*fung shui*).

It is also not unknown in China to blame the inappropriate *fung shui* of an original place of burial for family misfortunes, and thus to excuse the sale of a tomb for mere profit. The bones, in a jar, are then stored away in sheds, or, if there are rocky hills or mountains at hand, are put under overhanging rocks or in whatever place offers. De Groot [13] says that the "potted Chinamen," as foreigners ludicrously call these reburial jars, are pretty safe anywhere, for they are unglazed, of the cheapest possible pottery, and not worth the risk of stealing, for in China the laws exact severe penalties for disturbing human bones, and most of the people are very superstitious about doing so.

Chinese customhouse officials deal with many sets of bones in the luggage of repatriating emigrants every year. These are the bones of relatives or friends who have died abroad, brought home to be either entombed or added to the numberless "potted" skeletons of China.

Reburial in China has been in vogue from very early time, although always decried if done merely for the sake of the gain to be derived from the sale of the tombs of one's ancestors. It was approved in the case of a stranger who was to be forwarded to his native place, and this gives reason to suspect the influence of expatriated Chinese in the jar burials on Dalupiri. De Groot quotes ancient records showing that in the early part of the seventh century there was methodical reburial in grottos by the tribes, then known as Man, who inhabited Hupeh and northern Kiangsi. Of the entire country of Kwan-sin in Kiangsi it was said only two centuries ago: "Two or three years after the interment they open the coffins, without any palpable reasons, wash the bones till they are clean, place those of each corpse separately in an earthen jar, and bury the latter in the ground." There is, or at least was at the end of the last century, an article in the legal code prohibiting this practice, which may not, therefore, still survive. In many parts of China they use small wooden coffins for reburials, but in the South, as for instance in the

[13] De Groot, J. J. M., *The Religious System of China* (Leiden: E. J. Brill, 1897), Vol. III, Book I, "Disposal of the Dead"; Part III, "The Grave" (Second Half). See Chapter XIII, pp. 1057 ff., "On the Custom of Re-burying Bodies in Other Graves; Urn Burials."

maritime districts of Amoy and Kwangtung, disposal in jars is customary. Jars are likewise used for the primary burial of young children.

One is forced to wonder whether the ancient inhabitants of Dalupiri and Camiguin may not have been strongly influenced by contacts with South China. Miller refers to the legend of the Chinese pirate Li Ma Hong getting sulphur for making gunpowder at Camiguin. If Li Ma Hong had the knowledge of where to go, and risked the danger of the fierce tide rips to land there, it is a fair supposition that the island had been known to the Chinese from considerably more ancient times. It is almost unthinkable that a raider of the rich island of Luzon would venture to make a most perilous landing at such a place as Camiguin unless he well knew that something more valuable was to be found there than appearances would indicate.

Burdett's articles also contain a reference to Li Ma Hong that is very interesting indeed. He says: ". . . when exploring Calayan, a neighboring island, the natives there had told me many interesting stories of Limahong, the great Chinese pirate, who in years gone by had ravaged Lingayen and adjacent parts. He made a sort of base at a place called Ibo, on the westward side of Calayan, and from there used to send his junks to Camiguin to collect the sulphur and saltpeter to be found there, bringing it back to Calayan where he manufactured it into gunpowder and stink-pots, preparatory to his attack on Luzon later on when the monsoon was favorable." (It is impossible that saltpeter could have been found on Camiguin.)

Although it would be absurd to ascribe to the legendary visit of Li Ma Hong the archaeological evidence of long occupation of the islands, it would be quite in order to test well the hypothesis that in Li Ma Hong's time there came to an end a commercial and cultural contact of long standing between China's seamen and the islands to the north of Luzon.

The presence of a few shards of Chinese blue-and-white trade porcelain on Dalupiri has no greater significance than it would anywhere else in the Philippines. Since the ancient Filipinos as well as the Malayan peoples to the south held Chinese jars and other porcelain articles in the highest esteem, and kept them carefully as heirlooms from generation to generation, it would argue nothing as to the Chinese origin of a burial custom even if burial jars actually of Chinese origin were sometimes found.

On Dalupiri the people said they knew particular graves in which the jars had dragons around the top, but the tale broke down completely when an attempt was made to verify it. Absolutely nothing of the sort was found. (Note, however, Burdett's positive statement, which I disbelieve, that he himself found a *burial* urn, apparently Chinese or Japanese, with a dragon running around the outside.) Since I also was told the story of the dragon-jar burial on Dalupiri, but could find nothing to establish it, I believe the similar report for Camiguin to be a fable, which Burdett believed and unconsciously transferred to his own experience in writing his articles many years later.

The attack of Li Ma Hong on Manila was made in 1574–75. His depredations extended from Cebu to Pangasinan, but in the fullest accounts of him that I find (those of Isabelo de los Reyes [14] and of Paterno [15]) there is no mention that he visited the Babuyanes. There is no especial reason to doubt the reported tradition, however, for the visit of Li Ma Hong took place over a century before the migration of the Babuyanos to Luzon, and in their new home the tradition might have been carried on. Furthermore, nothing is more likely than that some remnants of the population may have been left on the small islands, destined to lose their identity through visiting back and forth with Luzon, but helping to maintain the tradition.

Chinese influence in the Babuyanes could not have been sufficient to affect the language, for at the time the inhabitants were moved they seem to have used a language related to Ibanag. Scheerer holds the theory that Ivatan, the present language of the Batanes Islands, was earlier the tongue spoken on the Babuyanes, and that it was carried northward, being replaced in the Babuyanes by a dialect from Luzon. If his theory is correct, the migration to the Batanes probably preceded the arrival in the Babuyanes of people using jar burial. At any rate there is as yet no report of this custom from the Batanes.

The volcanic craters of the northern end of Formosa have long been worked by Chinese for sulphur in much the same way that we may imagine the pirate crews of Li Ma Hong to have worked those

[14] Reyes y Florentino, Isabelo de los, *Filipinas: Articulos varios . . . sobre etnografia, historia y costumbres del pais* (Manila: J. A. Ramos, Editor, 1887), "Li-Ma-Hong," pp. 43–65.

[15] Paterno, Pedro A., *Historia de Filipinas* (*Apuntes*), Tomo II (Manila: Imprenta "La Republica," 1908), pp. 175–279.

of Camiguin. As a matter of fact, the sulphur so obtained in Formosa seems to have been of importance in later times only as an article of contraband trade with southern China, since the Chinese officials in Formosa had orders from the home government not merely to stop the production and shipment of sulphur, but even to destroy the deposits by burning them and covering them with earth. The reader interested in these absurd orders and the no less absurd efforts to comply with them will find a diverting account in Davidson's *Formosa.*[16] From the standpoint of this article, it is important that voyages to procure sulphur may have been made to volcanic islands from China long ago, and the tradition of such voyages to Camiguin may have been quite alive down to the time of Li Ma Hong, especially among the adventurous. Chinese to work the deposits may have been left by the ships, and these might well have set an example of jar burial to the islanders, for they would surely have attempted to provide for the return of the bones of dead comrades to China. Disposal in jars would have been the most ready means to facilitate such an end. The permanent marooning of a group of Chinese might well have established a custom.

OTHER ORIENTAL ANALOGIES

Although the similarity with Chinese custom is so striking that it must be taken into consideration, there may nevertheless be no close connection between the jar burials of the Philippines and the preservation of disinterred bones in jars in southern China. In fact, there is a possibility that the connection might be very remote indeed, for the disposal of bones in jars seems restricted to that part of China where in ancient times the cultural and racial affiliations were largely with peoples to the south, who were the peoples that had supplied some of the migrations southward, eastward, and northward, through the islands of the East Indies, into the Philippines. One does not have to go to the mainland of Asia for a parallel to a jar ossuary for disinterred bones. The writer has referred to this matter in another article,[17] where the interested reader may find references to stone jars used as ossuaries by the Dairi Batak west of

[16] Davidson, James W., *The Island of Formosa, Past and Present* (Yokohama, Shanghai, Hongkong, and Singapore: Kelly and Walsh, Ld., 1903), pp. 495–504.

[17] Bartlett, H. H., "The Sacred Edifices of the Batak of Sumatra," *Occ. Contrib. Mus. Anthropol., Univ. Mich.*, No. 4. Ann Arbor, 1934.

Lake Toba and by the Toba Batak of the Island of Samosir in Lake Toba, northern Sumatra. In the vicinity of Besoa and Bada, central Celebes, there are great jar-shaped stone "vats" which are probably tombs or ossuaries. They have been described and excellently illustrated in an article by H. C. Raven,[18] who cites earlier references to them. In Minahassa, northeastern Celebes, the Sarasin brothers [19] found that the dead were placed in stone urns. Grubauer [20] reports that the Tolambatu of southeastern Celebes make a secondary disposal of the bones of the dead in earthen jars which are placed in rock tombs. The jars, which he calls "gussys," are of Chinese origin, like those used by the Dayak and Dusun peoples of Borneo for the same purpose.

Urn burial is, of course, well known in the Orient. The following notes have been assembled in a cursory glance at the literature.

In the Wynaad, southern India, urn burials have been discovered by L. A. Cammiade.[21] At his first site the urns were buried upright, were either pointed or rounded at the base, and covered by stone slabs, and one had a shallow, rimmed, pottery cover also. Some of the jars would receive a squatting body, whereas one (the neck was only about five inches in diameter) could have been used only for bones. The burial jars contained other pottery vessels and one had beads. In all there were decayed bones, but no traces of charcoal or ashes. The second and third sites yielded similar vertical burial jars, one containing a crystal bead. There were no stone covers, and no signs of cremation. The fourth site yielded large and small urns, and likewise two types of urn covers, the usual shallow, saucer-like ones and others of flowerpot shape. Each urn contained a single pot, and some yielded crystal and carnelian beads, and small iron chisels. A single urn at the fifth site yielded eight small pots and an iron chisel. (The author notes that in Tinnevelly burial urns are found almost full to the top with pots and other objects.) The report of Cammiade is the more interesting and valuable because the

[18] Raven, H. C., "The Stone Images and Vats of Central Celebes," *Nat. Hist.*, 26 : 272–282. 4 pls. 1926.

[19] Sarasin, P. and F., *Reisen in Celebes.* Wiesbaden, 1905.

[20] Grubauer, Albert, *Celebes: Ethnologische Streifzüge in Südost- und Zentral-Celebes* (Hagen i. W. und Darmstadt: *Folkwang-Verlag G.M.B.H.*, 1923), pp. 28–30.

[21] Cammiade, L. A., "Urn-Burials in the Wynaad, Southern India," *Man*, 30 : 183–186. 1930.

beads were turned over to a specialist, Horace C. Beck, for study, and he has reported upon them in interesting articles accompanying the one on burials.

Cammiade [22] likewise reports on urn burials in the Tinnevelly district of Madras Presidency. Here he excavated urns, one of which was covered by a bowl-shaped vessel. At more than one locality the bones in some jars were artificially arranged, some of them being placed in small pots within the big jar, indicating that the burials of disarticulated skeletons marked the final stages of funeral ceremonies. Other jars contained the remains of bodies that had been buried entire, in a squatting position. In Tinnevelly, as in the Wynaad, iron chisels were found in the urns, and also other iron implements, various types of beads, numerous small pots, clay pipes, and coins of about the eleventh or the twelfth century. Cammiade says that in many districts of the extreme south of India urn burial is the common type of interment. When the urns occur in a closely packed cemetery, no surface mark or monument is ordinarily found. Stone circles, however, mark solitary urn burials in Tinnevelly, and are also found in one large cemetery. The urn-burial sites of South India are mined for the beads which they contain.

These true jar burials are closely similar to the cyst graves within stone circles that are very common in South India. Jars always accompany each cyst grave, and in some localities cyst graves and jar graves occur together. Hunt,[23] in an interesting article, states that the cysts are surrounded by jars, in many cases "so far from the center of the cairn that they lie under the stones of the circle." (He notes regarding his use of the word "cairn": "They have been called cairns by many writers and the word will be used in this paper, though the height of the rubble stones inside the circle does not fully justify its use.") Hunt records that burials of the "Cairn Period" in Hyderabad State alone cannot be far short of a million!

Hutton [24] reports in Assam the special preservation of the skull by the Konyak group of Nagas, by the Chang and Phom Nagas, by the Siyin Chins, and occasionally by other Kuki tribes, "the body

[22] Cammiade, L. A., "Observations upon Ancient Sites in the Neighborhood of Kalugumalai, Madras Presidency," *Man*, 30: 187–189. 1930.

[23] Hunt, E. H., "Hyderabad Cairn Burials and Their Significance," *Journ. Roy. Anthropol. Inst.*, 54: 140–156, Pls. XXII–XXVIII. 1924.

[24] Hutton, J. H., "The Significance of Head-Hunting in Assam," *Journ. Roy. Anthropol. Inst.*, 58: 399–408, Pls. XXXVIII–XLII. 1928.

being left to rot while the head is buried in a pot or a stone cist or secreted in a niche in a cliff." A custom of this sort can be traced with gradual variations through much of Indonesia and the Philippines to Formosa.

University of Michigan

EXPLANATION OF PLATE I

Fig. 1. A rough wall, presumably a lookout station, perched on the brink of the sea cliff only a few yards from the entrance to Manolong cañon. Sea rovers with any knowledge of Dalupiri would naturally have made their landing at this point if in need of fresh water. A lookout stationed here could have slipped unobserved into Manolong cañon through a lateral cleft in the vertically eroded coral rock, in order to notify the inhabitants of the approach of strangers. Behind the wall is a deposit of broken pottery, containing some fragments of blue-and-white Chinese porcelain.

Fig. 2. Broken ossuary jar chinked firmly into place in a cavity of the rough coral rock at the locality shown in Figure 1. This jar, although broken and exposed to the weather too long to contain any human remains, was nevertheless interesting as indicating that dry bones were presumably preserved in jars after a preliminary burial or exposure of the body, for the mouth was too small to have admitted the whole body of even a child.

FIG. 1

FIG. 2

View of the perfect stone burial circle which was chosen for excavation, near the brink of Manolong cañon, Dalupiri Island. The outer diameter was about fourteen feet and the depth, before removing loose rocks, about three feet

EXPLANATION OF PLATE III

Within the stone circle, after it had been cleared of loose stones. The lower burial jar was complete and in place at the center of the circle. It was surrounded by fragments of the upper, cover, jar, which was enough larger than the lower one to fit over its rim but was probably of the same shape. Excavation disclosed that the rim of the cover jar, although cracked into several pieces, was still held firmly in position by the tightly fitted and chinked floor of coral rock boulders, the level of which was a few inches above the overlap of the two jars. The original fairly level floor was entirely distinct from the loose boulders that had been tumbled into the circle from the top of the wall, and its position was such that before the grave was disturbed the upper, inverted, jar must have protruded a foot or so above the floor at the center of the enclosure, like the hub of a wheel. The fragility of such a construction accounts for the partly demolished state of the graves. The loose boulders above the floor level were easily tossed away, but the floor stones had to be laboriously pried out with a bar, since they had been firmly and quite closely fitted.

The lower jar after removal. Dimensions, *c.* 51 centimeters at top, 51 centimeters tall. (Mus. Anthropol., Univ. Mich., No. 17556)

EXPLANATION OF PLATE V

FIG. 1. Chinese jar ossuaries. Hill rising behind the former walled village of Na Chin Moy, Kowloon, Hongkong leased territory. (The village has now been razed.) This picturesque hill has many large residual boulders protruding above the scanty barren soil. Surrounding these boulders, by preference, but sometimes elsewhere, villagers place the jars containing the bones of the dead, thus disposed of after a preliminary burial in a place of good *fung shui*.

FIG. 2. Another view of jar ossuaries on the same hill at Kowloon. These Chinese pictures suggest strongly that the jar burials on Dalupiri Island are quite possibly traceable to Chinese influence, although the association of jars with stone circles would indicate a stronger analogy for the Philippine burials with southern India.

FIG. 1

FIG. 2

RIZALITES — PHILIPPINE TEKTITES — WITH A DESCRIPTION OF THE PUGAD BABUY SITE

RALPH BUSICK

HISTORY OF THE DISCOVERY OF RIZALITES

DURING 1926 the first rizalite that attracted the attention of Manila scientists was found in an archaeological site at Novaliches, Rizal Province, where the government was making extensive excavations for the construction of the dam and reservoir which now supply the city of Manila with water.

Because of the fact that, in the main, this strange body seemed to resemble ordinary "natural" glass, yet varied in composition and properties sufficiently to arouse interest, there was considerable doubt and some disagreement among local scientists in regard to its source. Generally, however, it was thought to be of volcanic origin.

For two years, according to Beyer,[1] matters stood thus — until Overbeck [2] visited the Philippines, saw this tektite and others found in the same region, and suggested that they were very similar to billitonites, tektites found on the island of Billiton in the Netherlands East Indies. This observation redoubled Beyer's interest in the tektites, and led them to conduct an intensive search for specimens throughout that immediate region, with most fruitful results on what came to be known as the Pugad Babuy site. It was in connection with the research on this site that the writer worked with Beyer during the later months of 1933, all of 1934, and January and February of 1935.

It happened that, shortly after the first discoveries, an American by the name of Lake, who lived in the neighborhood of the barrio of Pugad Babuy,[3] became interested in collecting the tektites and, in the course of some months, gathered approximately four thousand

[1] H. Otley Beyer, professor of anthropology and archaeology and head of the department of anthropology and sociology, University of the Philippines.

[2] Hans Overbeck, of the colonial service in the Netherlands East Indies.

[3] *Pugad babuy*, a Tagalog phrase, literally translated means "hog nest." The natives recently changed the name of the barrio to "Torres Bugallon," the name of a prominent resident they wished to honor.

specimens, a large number of which he turned over to the Bureau of Science in Manila for its museum. The obvious plenitude of the tektites led Beyer to conclude that here was one of the richest fields of these bodies on earth. Assuming that, inasmuch as there had probably been no really scientific approach to the task of collecting them, a cursory examination of the ground in the Pugad Babuy region actually had unearthed comparatively few, and believing that there must be great numbers of them remaining, he undertook the work of gathering the specimens.

BEYER'S METHOD OF COLLECTING

At the outset Beyer decided to name the Philippine tektites "rizalites" because — to use his own words — "the first specimens were found in Rizal Province — and this name has now been quite generally accepted."

Through years of experience in collecting archaeological specimens in the Philippines, while he was at the same time engaged in a multiplicity of other pursuits, Beyer had developed a specialized technique for this kind of research. He first visited a prospective site to determine its characteristics and potentialities; then he aroused the curiosity of the inhabitants by showing them specimens of the tektites and asking if they had any. Great numbers were being picked up, of course, during Lake's activities, and the natives were familiar with the "stones." It now remained only for Beyer to gain the people's confidence, to establish a set of reasonable prices for specimens collected, and to become thoroughly acquainted with the residents of the barrio and the location of their homes and farms, or the extent of the region over which the individuals might have the privilege of searching.

When he had accomplished these things, he drew a small map showing the location of the richest deposits and the general topography of the site. Thus he was able to record the concentration or the diffusion, as the case might be, of his collections.

His practice was to visit the barrio quite frequently, almost invariably once a week during the rainy season (June to November), but missing a week occasionally during the dry season (December to May). Centrally located in the barrio was a *tienda* ("small store"), where the proprietor graciously permitted him to conduct the business of buying the specimens from the collectors.

Before long the children of the entire neighborhood were searching for tektites to sell, and it was unusual indeed, after the first few weeks, for an outsider to find one of the objects on the ground.

Beyer paid the children according to the number and the rarity of specimens in their finds, augmenting his payment with candy and fruits from time to time. Upon receiving a week's collection from a child he would write its name on a slip of paper, together with the amount paid for the lot, and place them together in a small sack. Frequently, too, if the collection happened to be extraordinary for some reason or other, he would question the finder closely to make certain of the approximate spot where the specimen or specimens had been found. Under this system he could determine within a few yards where every lot of specimens had lain.

Not content with this manner of collecting the majority of the tektites found in one week Beyer nearly always made a trip to the outlying homes on either side of the dirt road that bisected the site.

When he had finished this part of his work he returned to Manila and there in his office wrote an account of the trip. Later he would carefully clean the specimens and catalogue them.

CHARACTERISTICS OF RIZALITES

Bodies classified by geologists and archaeologists as tektites have been found in various parts of the world, and have been named after the regions where they were found. The best known of these include moldavites, found in the Moldau district of Bohemia and in Moravia and supposed to be associated with the late Tertiary or Recent period; billitonites, found on the island of Billiton in the East Indies; australites and the so-called obsidianites, found in Australia; Darwin glass, sometimes called queenstownite, found in Tasmania; and the pseudotektitic amerikanites found in Colombia and Peru, South America.

These bodies are of various forms described as ellipsoidal, pear-shaped, button-shaped with overhanging edge, cylindrical (slender), and cone-shaped. Beyer says that "they occur chiefly in certain regular forms such as small spheres, ovals, cylinders, dumbbell-shapes, and pointed drops (often, in rare perfect forms, with a slender tail)." Usually a fragment gives some suggestion of the shape of the tektite from which it was broken. Beyer continues:

Such regular shapes could only be formed in nature by the revolution of a liquid or semiliquid substance in the atmosphere. These objects have also been proved to be of prehistoric origin in the places where found. The only possibility for the natural formation of such bodies upon the earth was formerly thought to be the violent ejection of liquid lava from large volcanoes. However, the chemical composition of the tektites does not correspond to the known products of any earthly volcano — and, recently, a new theory has been suggested that accounts for them on the basis of their resulting from the fusing of a portion of the earth's crust through the impact of a huge meteorite which splashed molten sand and rock high into the air. This theory has met with many objections and has been accepted only by a few scientists. The cosmic theory still remains, at the beginning of 1935, the only one which explains all of the observed facts.[4]

Rizalites have the same chemical composition that other tektites have; that is, in general, they possess the natural content of obsidian — 70 per cent to 90 per cent SiO_2 — with a higher percentage of iron and magnesium, and an excess of calcium and potassium over sodium. In the main, however, according to the *Encyclopaedia Britannica*, tektites do not show the incipient crystallization characteristic of all obsidians.

Nearly all rizalites are distinguishable from other tektites in that they have a pitted surface similar to that of an orange skin, whereas the billitonites, for example, have a deeply grooved surface of "gutters" that often resemble worm tracks. Rizalites are opaque and, to the casual observer, appear to be black, but when held between the eyes and the light reveal a deep olive green verging on black.

The sizes of the rizalites found before 1935 range from that of a small pea up to that of a lime or small lemon. The largest does not weigh more than 250 grams.

Fragments of rizalites which obviously have long lain exposed show, on the broken surface, patination or "surface sculpture" quite similar to that typical of obsidian fragments, but there is no sign of the layerlike, or laminated, structure of Philippine obsidian.

Native peoples have made use of tektites in past ages wherever the bodies have been found, and the Filipinos are no exception. Though the majority of the larger rizalites remain comparatively untouched by human utensils, a great number of the smaller, odd-shaped ones do show evidences of having been artifacts — drills, scrapers, and the like. Moreover, the natives have names for the bodies. Concerning this matter Beyer writes:

[4] Beyer, H. Otley, "Philippine Tektites," *Philippine Magazine*, 32 : 542. 1935.

Scientists are not the only proponents of the meteoritic theory of tektite origin. Long ago, native peoples, seeing these round black spheres and cylinders scattered over their fields after a heavy thunder shower, came to the conclusion that they had fallen from the sky. In the Philippines, the tektites are variously known as *taeñg kulog* (thunder dung), *taeñg bituin* (star dung), and in one province *batong arao* (sun stones).

Outside the Philippines, cosmic or at least heavenly explanations are equally common among native peoples . . . .

The utility of the tektite glass for manufacturing flaked implements was also recognized by early man. European Moldavites have been found among the flaked implements of the old Stone Age; while practically all the Philippine and Malaysian peoples of Middle and New Stone Age times manufactured arrowheads and flaked tools from tektite glass wherever it could be found. This was true also in Australia — although many more were there carried about by the natives as valued charms.

In Philippine graves dating from the Prehistoric Iron Age, tektites have also been found, showing the characteristic "carry-polish," which indicates that they were used as charms or amulets by the people of that time. In Indo-China tektites were also venerated to some degree by the late Bronze Age people, and stone images dating from the early centuries of the Christian Era have been found with polished tektites set into the eyes of the gods.[5]

THE PUGAD BABUY SITE

Although the barrio of Pugad Babuy is hardly fifteen kilometers from the heart of Manila, off what is known as the Manila North Road, it actually lies within the province of Bulacan, adjacent to the Novaliches district in the province of Rizal, where were found the first tektites that caught the scientific attention of the outside world.

The most productive section of the site is on a slight knoll which rises gently above the surrounding terrain to a height of not more than thirty or forty feet. It forms a part of the Marikina River Valley and is not more than a hundred feet above sea level. It is roughly circular and covers an area of perhaps five square kilometers. Over this area grow a scattering of bamboo and trees, most of the latter fruit trees. Farm produce consists chiefly of rice, for which a number of terraces have been built. Sugar cane and some vegetables, too, are grown, but not in abundance.

The soil is what is known as red laterite, a thin layer of which covers the tuff or tufa, or adobe, as it is generally called in the Philippines. Outcroppings of the tufa in various spots over the site suggest that the topsoil is not more than a few feet thick anywhere in the region. Inasmuch as most of the rizalites were found after a

[5] Beyer, *op. cit.*, pp. 581–582.

rainfall or on a freshly plowed field, it is obvious that they lay close to the surface, not within the tufa.

During the dry season the size of the weekly collections of rizalites decreased remarkably in number; but immediately the annual rains began to fall, the collections increased. A trip which did not produce at least a hundred specimens was a disappointing one, and there were occasions when Beyer took as many as seven hundred or a thousand back to Manila with him. The result of this fruitful collecting was that by the end of 1934 his collection numbered somewhere between 25,000 and 30,000 specimens. Among these the rarest were cylindrical, dumbbell-shaped, drop-shaped, and those weighing above 150 grams, of whatever shape.

Of things important to archaeologists or geologists, other than rizalites and obsidian flakes (some artifacts and some not), the Pugad Babuy site was not particularly productive. Beyer did not reject the obsidian, specimens of which invariably accompanied the tektites, though he was not particularly interested in it.

DISCOVERIES SINCE 1934

Important discoveries of other similar bodies in the Philippines were made in 1935, after the writer left Manila. Concerning these Beyer says:

> Near the end of September of this year, a very remarkable new tektite site was located at the very edge of Manila, in the Santa Mesa district. In addition to a plentiful supply of true Rizalites, three other strange forms of tektite-like bodies turned up. The first of these is a grey obsidian-like glass which tends to show the same sort of internal structure as ordinary volcanic obsidian — but which here appears in strangely rounded and sculptured small bodies of a distinctly tektite-like appearance. The second of the new classes of material shows a much more uniform glassy consistency — without the laminated body common in most Philippine obsidian — and although quite translucent, is of a color varying from a brownish-violet to almost a rose-pink. The outside appearance of these bodies is so nearly like that of true Rizalites that they can usually be distinguished from them only by transmitted light, showing the difference in color. Still a third class of new material found in the Santa Mesa site is greenish-yellow in color, but otherwise has the same glassy consistency and pitted surface as the true Rizalites.[6]

The bodies here described he calls "Philippine Amerikanites" because of their close resemblance to the tektites found in Colombia and Peru, as mentioned above. More recently, in a letter to the writer,[7] he specifies the confines of the district and adds:

[6] Beyer, *op. cit.*, p. 543. [7] Dated May 27, 1936.

The part of this new area nearest Manila is simply an extension of the Santa Mesa site, and shows Amerikanites as well as Rizalites. But the new Kubao site proper occupies the higher parts of the ridge and contains only the Pugad-Babuy type of material — but with a much more brilliant luster and deeper surface sculpture. The quantity is not as great as at Pugad Babuy, although the site is sufficiently rich. The most important part of these new finds is due to the fact that extensive new road-work and street-building in that district has given us a great number of excellent cross-sections through the entire group of soil layers down into the solid adobe. This quickly enabled us to determine exactly where the tektites lie — and we were able to prove definitely that they all come from a peculiar stratum only six to eight inches thick in most places.

This tektite-bearing layer lies just above a fairly thick layer of reddish material chiefly made up of decomposed adobe but below other soil layers of varying thickness and color. It is characterized by the presence of thousands of little nodules (called pisolites by geologists) composed mainly of iron and manganese. What connection there is between these pisolites and the tektites, if any, still remains to be determined. It has been possible in this district to get a much clearer idea of the original distribution and characteristics of the tektite material. I think that what we are finding here now may add a great deal to an understanding of the tektite question, and narrow the field of future research considerably beyond the point to which all previous research could carry us. . . .

I wish to add that the Kubao district produced the largest tektite yet found in the Philippine Islands, now 275 grams, and a very fine-looking specimen.

Certainly the great numbers of bodies discovered on the Pugad Babuy site and in regions near by ought eventually to yield considerable information concerning the origin of tektites and the reasons for variations in form, size, and color, and for their irregular distribution. Though it is generally agreed that the bodies are not of volcanic origin, there still remains the fact that an abundance of them, comparatively speaking, has been discovered in volcanic regions.

Again, what is to account for the strange circumstance that the bodies are found in a definite "belt" around the earth? Can it be that this is merely an accident? Or are there many others not in this belt yet to be discovered?

Finally, is Spencer's "splash" theory that the bodies are all merely fragments from one great meteor the answer to the question, or is each tektite an individual meteorite which has struck the earth independently of the others?

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A BURIAL SITE ON THE ISLAND OF SAMAR, PHILIPPINE ISLANDS

CARL E. GUTHE

THE town of Catbalogan is a port on the west coast of Samar, one of the eastern islands of the Visayan or central group of the Philippine Archipelago. A road runs northward from the town, roughly parallel to the coast. A few miles north of Catbalogan it crosses a small semicircular valley, near the village or barrio of Egid. When this road was built the contractor dug shallow pits on each side of the right of way to secure earth for a fill. On the beach side only, less than a hundred yards from the sandy shore, he came upon jar burials which were said to have been covered with flat stones in which grooves had been cut to receive the rim of the jar. He is reported to have found some jars with others inverted over them.

In February, 1923, I spent a week excavating undisturbed areas between and adjacent to two of the shallow pits made by the contractor. These pits were separated by a ridge of earth about three feet wide. In addition to disclosing the badly confused remains of two burials encountered by the contractor, one of which included a stone cover with a groove in it, the excavations revealed ten undisturbed burials, five of which were those of adults buried at length, and five of which were jar burials containing the remains of very young children.

The area in which this cemetery was located was apparently an old clearing, for it was covered with high grass and underbrush. The contractor's two pits combined occupied a roughly oval space thirty meters long by nineteen meters wide, with the long axis running approximately north and south, parallel to the road, which was seventy-five meters east of the sandy beach and twenty-four meters east of the center of the two pits. (See Fig. 1.)

A short distance south of the pits the clearing ended abruptly and a woods began. To the north the small valley became swampy and muddy. The valley floor was formed by an irregular stratum of

black sandy loam, containing vegetal mold and many fine roots. This loam was forty to forty-five centimeters thick where the contractor's pits were dug, and was underlain by clean, light-colored

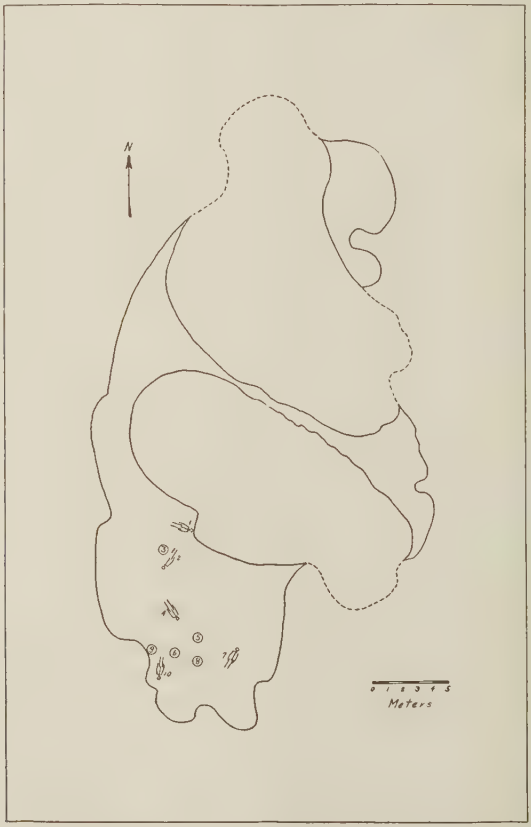

Fig. 1. A chart of the excavations at Egid. The unaltered portions of the periphery of the contractor's pits are shown by dashed lines

sand, in which occasional shells and fragments of native-ware jars occurred. Immediately to the north of these pits the black loam became thicker. At the point where our excavations in this direction were discontinued this loam was wet and heavy and had attained a

thickness of over a meter. In it occasional fragments of blue-and-white and green Chinese ceramics were found, associated with sherds of red native ware and a few fragments of charcoal. These materials were scattered so sparsely through this deposit that further excavations in this direction were discontinued.

All the burials were found in the sand stratum underlying the darker sandy loam to the south of the contractor's pits, in an area about ten meters long and nine meters wide. The pits and the subsequent archaeological excavations were carried to a depth of about one and one-half meters.

The five adult burials were all at full length, on the back, with the head resting either on the occiput or on the left side. Although native wooden coffins are known to have been used in the Visayan Islands, no traces of wood were found with these burials. All attempts to determine the edges of the burial pits failed, as might be expected in such clean sand deposits. The depths of these burials were remarkably uniform, ranging from 79 to 113 centimeters. Three of the five adult burials had no furniture of any kind associated with them. In burial number 4 a small piece of iron was found under the left ear, and in the right hand were the remains of an iron dagger. On the left chest of burial number 10, beside the left humerus, was a large iron dagger, bent nearly double. The handle, which had probably been of wood, had disintegrated, but the remains of iron and bone inlays could be identified. Skeleton number 2, which had been disturbed by a subsequent jar burial, will be referred to later.

In clean sand deposits of this nature the seeping of surface water tends to destroy any noteworthy record of stratification. The only evidence of this nature which could be obtained occurred with the first burial discovered, that of an adult, extended at full length, with the hands resting on the pelvis (Pl. I, Fig. 1). The head was toward the east, with the face turned toward the left shoulder. There was absolutely nothing associated with the bones. At this point the dark surface layer of loam was 25 centimeters thick, below which lay the sand stratum. In it was a refuse deposit, 14 centimeters thick, the top of which was 49 centimeters below the surface and 24 centimeters below the base of the black loam layer. It contained the shells of seventeen varieties of edible shellfish identified by the native laborers, fragments of native pottery, and occasional pieces of burned sand-

stone. This well-defined and unbroken refuse layer extended over the entire burial and 150 centimeters to the north and 225 centimeters to the south of it, that is, beyond the limits of a reasonably large burial pit, which indicates that the burial had been made before the refuse had been laid down and well before the black loam had been deposited.

The five jar burials were equally consistent in their general nature. All contained the bones of very young children. The condition of these small fragile bones was so bad that in only one case was it possible to ascertain that they were in anatomical position, showing the body completely flexed. The size of the jars was such that the entire body of the infant could have been placed in them. It is improbable that secondary jar burial was practiced at this site, although in other parts of the Visayan group evidences were found of cleaned adult bones having been placed in jars. Each of the jar burials at this site contained a number of small colored beads — white, red, yellow, orange, and blue. In the bottom of each was a hard white deposit, the materials of which may be of animal origin, but which have not yet been identified. Every one of the jar burials was covered with a large flat stone, and one, burial number 6, had two flat stones on it. The upper surfaces of these flat stone covers, the depth of four of which ranged from 63 to 91 centimeters, were well within the sand layer. A fifth jar, that of burial number 3, had been placed in a shallower pit, for the stone was only 42 centimeters below the surface and the base of the jar 89 centimeters deep (Pl. I, Fig. 2). The depth of the bases of the other four jars, approximating that of the pit dug to contain them, was slightly greater than that of the extended adult burials, and varied from 99 to 135 centimeters below the surface.

The five burial jars were all very similar. They were heavy thick native ware, with sand temper. The surface color was various shades of reddish brown, and the interior of the wall was in many cases black. Three were globular, and one had a definite conoidal base (Pl. II, Fig. 1). The shape of the fifth could not be determined. In jars which had not been too badly shattered there was evidence of a narrow shoulder, a short vertical rim, and a wide mouth. In one jar rim sherds were found showing a plain lip. In two others the lip was decorated with a diagonal fingernail indentation. The jars were unslipped, roughly smoothed, and without decoration on the body.

FIG. 1. Burial No. 1, Egid, Samar

FIG. 2. Burial No. 3, Egid, Samar. The trowel marks the location of the cover stone

FIG. 1. Burial No. 5, Egid, Samar

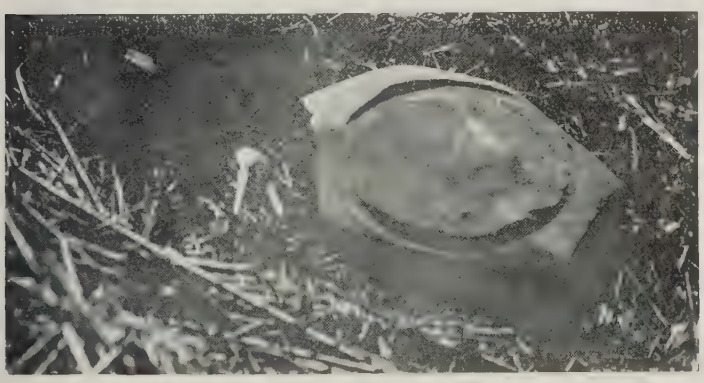

FIG. 2. The grooved cover stone *in situ*, Egid, Samar

The diameters of the body ranged from 30 to 42 centimeters; the height, from about 27 to 41 centimeters. The body sherds varied from 5 to 10 millimeters in thickness.

The stones covering the jars were roughly rectangular undressed slabs of soft grayish sandstone, ranging in thickness from 5 to 10 centimeters. They had apparently been shaped by breaking the edges. The smallest was 24 by 30 centimeters, the largest 42 by 50 centimeters. None of them possessed grooves for the rim of the jar, although one, covering burial number 8, still retained the imprint of the jar rim, a circle 26 centimeters in diameter.

The grooved stone which was associated with one of the burials disturbed by the contractor's crew has a shallow depression 4 centimeters wide and 1.5 centimeters deep at the greatest depth (Pl. II, Fig. 2). It does not have a constant depth; in fact, in two places the circle is broken. Obviously an attempt was made to have the bottom of the ring in a single plane. The circle formed by the outer edge of the groove has a diameter of 53 centimeters. The outer edge is smoother and better formed than the inner one. The stone was similar to the six found in the excavations, but much larger, measuring 76 by 60 centimeters.

The relationship between burials 2 and 3 furnished an interesting bit of stratigraphic record. When the extended adult burial number 2 was uncovered, it was found that the skull, the left part of the trunk, the left arm, and the left femur were missing, although both pairs of the lower leg bones were present. This skeleton lay at a depth of 79 centimeters below the surface. When it had been removed and the trench continued, jar burial number 3 was disclosed almost immediately. The jar lay just to the left of burial number 2, opposite the ribs. The base of the jar was 89 centimeters below the surface, that is, 10 centimeters lower than the floor of the extended burial. It was obvious that the extended burial was the older, for it had been disturbed at the time the pit was dug in which the jar was placed. Of course, it is impossible to determine the time interval which elapsed between these two interments.

Except for this association between two of the burials there was no direct evidence which could be used to determine the relative ages of the two forms of burial. However, both were found in close association within a small area. The pits which had been dug for both types were all carried to about the same depth. In addition, there

was a clearly marked difference between the methods of burial of adults and of children, which might indicate that the two customs existed side by side within one culture. For these several reasons I am inclined to believe that the extended and the jar burials were approximately contemporaneous.

The relative antiquity of the site can only be conjectured, owing to the rather unsatisfactory evidence. The presence, above burial number 1, of a thick unbroken refuse deposit, the top of which was 49 centimeters below the present surface, would indicate that at the time at which burial had been made the surface was at that level. This evidence, however, is inconclusive, for no similar stratigraphic record was found associated with any of the other nine burials. It is nevertheless worth noting that, with one exception, the stone covers of the jar burials were all below the level of this refuse deposit. Had the relatively thick layer of black loam which now covers the site been present at the time the burials were made, it seems probable that some of it would have been used in filling the pits upon the completion of the burial. To be sure, the action of surface water seeping through the sand might have leached out the dark color of the loam. Yet in that case considerable time would have had to elapse to remove all traces of such deposits from the pits of all ten burials.

The total absence of any Chinese ceramics with the burials may furnish an additional clue to their antiquity. On other islands of the Visayan group interments in the ground, as distinguished from cave burials, have had unbroken celadon plates associated with them. This phenomenon is entirely missing at this site, but may be explained as due to the existence of different burial customs in the other localities. However, the presence of fragments of glazed Chinese ceramics at some depth in the thickened black loam deposits just to the north of the burials indicates that such wares had been used in this locality for some time. Finally, the shapes of the heavy native-ware jars in which the burials were made do not resemble closely those of the red globular native-ware jars now in use in the region. The presence of iron and small beads in the burials does not preclude reasonable antiquity, for these articles seem to have been used by Filipinos for a very long time.

In conclusion, it seems safe to affirm that the five extended burials of adults and the five jar burials of infants encountered near the barrio of Egid are the remains of a cemetery which was used for a short

period of time by a relatively ancient Filipino community on the west coast of Samar.

The investigations reported upon in this paper were in the nature of a reconnaissance, and constituted only one of many studies made at a large number of sites in all parts of the southern Philippines during the course of the University of Michigan archaeological expedition to the islands in 1922 to 1925.

University of Michigan

FOLK TALES WHICH EXPLAIN HOW THE RACES OF MANKIND ACQUIRED THEIR COLORS

EUGENE S. McCARTNEY

AMONG the most engaging pursuits of the folklorist is the study of the dissemination of folk tales. Countless articles and volumes have been written on this general subject. The time has now come, however, when more effort should be devoted to an undertaking hardly less interesting, the collection of highly diversified stories which have grown up independently of one another and which owe their existence to the same psychological attitude of different peoples or to similar experiences. Stories of floods, for instance, occur in the lore of numerous tribes and nations.[1] Again, many peoples have traditions which assume that the original color of the crow and the raven was white.[2] One expects a tale to be carried from country to country, but I find it far more interesting to observe how one common idea gives rise to many tales totally unlike.

Whenever two persons or two races of markedly different colors are brought into contact for the first time the contrast is at once noticed and curiosity is aroused. The point may be illustrated by an experience of a Dutch traveler in a Bedouin camp in Arabia:

> . . . The boldest ventured to rub my bare arm with her hard, black fingers to see if she could remove some of the white. She cried out in astonishment when the white would not rub off.[3]
>
> The sleeve of my khaki shirt was pushed up — there it was even whiter!

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[1] It takes 225 printed pages to record the world's flood stories. See Frazer, J. G., *Folk-Lore in the Old Testament* (London: Macmillan Co., 1923), I: 107–332.

[2] See McCartney, E. S., "Folk Tales Which Account for the Blackness of the Raven and the Crow," *Pap. Mich. Acad. Sci., Arts, and Letters*, 12 (1930): 137–148.

[3] In Aesop, *Fables*, 13 (204), there is described the experience of a man who bought an Ethiopian under the firm conviction that his blackness had been caused by his owner's neglect of his bodily welfare. The purchaser tried all sorts of cleansers upon him and subjected him to many washings, but all to no avail. Compare the Greek proverbial phrase, Αἰθίοπα σμήχειν, "to wash an Ethiopian." A Negro seventy years of age once told me that he had given up washing and bathing because water had not made him any whiter.

The examination was continued to my throat and breast . . . [and even to less accessible parts of the body].[4]

Another example enlivens a book by the most romantic figure in the World War, Colonel T. E. Lawrence:

. . . Mohammed's mother knew herself old enough to be curious about me. She questioned me about the women of the tribe of Christians and their way of life, marvelling at my white skin, and the horrible blue eye which looked, she said, like the blue sky shining through the eye-sockets of an empty skull.[5]

A third illustration of the way the sight of foreigners affects an untutored mind has its setting on the other side of Asia:

Then Wang Lung knew that this was indeed a foreigner and more foreign yet than he in this city, and that after all people of black hair and black eyes are one sort and people of light hair and light eyes of another sort, and he was no longer after that wholly foreign in the city . . . . Nevertheless, through this experience Wang Lung learned what the young men had not taught him, that he belonged to his own kind, who have black hair and black eyes.[6]

Such curiosity about the contrasting color of the bodies of strangers generally leads naïve races to assume that their own forebears were the first people in the world and that the color of their own skin was the original color of all races. When a naïve mind reflects upon the differences in color the stage is set for the creation of an etiological story. It is this type of story with which the present paper is primarily, though not wholly, concerned.

COLORS OF THE SKIN ACQUIRED AT CREATION

According to some folk tales all the races of mankind known to the originators of them acquired the colors of their bodies at one and the same time. A simple Egyptian explanation says that the god Aton "distinguished one colour (race) from another."[7] Generally,

[4] Van der Meulen, D., "Into Burning Hadhramaut," *National Geographic Magazine*, 62 (1932): 397. Similar curiosity was manifested about Miss Stark when she visited the same part of Arabia. See Stark, Freya, *The Southern Gates of Arabia: A Journey in the Hadhramaut* (London: John Murray, 1936), pp. 238, 252, 256. Natives of remote parts of Persia who had seldom or never before seen a European woman were obtrusively curious about Miss Stark's person. See her earlier book, *The Valleys of the Assassins and Other Persian Travels* (London: John Murray, 1934), pp. 73, 101, 166, 285, 340, 347.

[5] Lawrence, T. E., *Seven Pillars of Wisdom* (Garden City, New York: Doubleday, Doran and Co., 1935), p. 235.

[6] Buck, Pearl S., *The Good Earth* (New York: The John Day Co., 1931), pp. 112–113.

[7] Breasted, J. H., *The Dawn of Consciousness* (London: Charles Scribner's Sons, 1933), p. 311.

however, there are circumstantial aspects in the tales of the differentiation of color, even though a god may play a part in them, as we may see from the words of an aged Negro on the banks of the Mississippi:

> In the beginning of the world, God, in order to people the earth, wished to create a man of each nation, to do which he took a clod of earth, kneaded it, and detaching pieces from it, fashioned in succession a *Negro*, a *Chinaman*, an *Indian*, and so with all the other peoples.[8]

An extremely naïve tale narrated by a Florida Negro recounts how colors were doled out by God along with parts of the body:

> Well, He give out eyes one day. All de nations come up and got they eyes. Then He give out teeth and so on. Then He set a day to give out color. So seven o'clock dat mornin' everybody was due to git they color except de niggers. So God give everybody they color and they went on off. Then He set there for three hours and one-half and no niggers. It was gettin' hot and God wanted to git His work done and go set in de cool. So He sent de angels Rayfield and Gab'yll [Raphael and Gabriel] to go git 'em so He could 'tend some mo' business.
>
> They hunted all over Heben till dey found de colored folks. All stretched out sleep on de grass under de tree of life. So Rayfield woke 'em up and tole 'em God wanted 'em.
>
> They all jumped up and run on up to de th'one and they was so skeered they might miss sumpin' they begin to push and shove one 'nother, bumpin' against all de angels and turnin' over foot-stools. They even had de th'one all pushed one-sided.
>
> So God hollered "Git back! Git back!" And they misunderstood Him and thought He said, "Git black," and they been black ever since.[9]

Other Negro lore assumes that God created people of the color of dust and allowed Nature to divide them into two races:

> A mocking-bird in the apple tree trilled for dawn while Cun Hester told how God made the first people out of dust. They were not black, not white, but the color of the dust of the ground. He put some in Africa where the sun was hot and it baked them black as tar. He put some in a country where winter-time covered the ground with snow. Cold weather bleached them white.[10]

Čuok, too, is a race-creating deity. The story in which he appears is noteworthy because the tellers, the Shilluks of the White Nile, recognize that they are an inferior race:

[8] Chamberlain, A. F., "Negro Creation Legend," *The Journal of American Folk-Lore*, 3 (1890) : 302, quoting from *Annuaire de l'Institut canadien de Québec*, 1878, p. 3.

[9] Hurston, Zora Neale, *Mules and Men* (Philadelphia: J. B. Lippincott Co., 1935), pp. 48–49.

[10] Peterkin, Julia, *Bright Skin* (Indianapolis: The Bobbs-Merrill Co., 1932), p. 180.

Čuok hat alle Menschen aus Erde geschaffen. Als er daranging sie zu schaffen, ging er von Land zu Land. Im Lande der Fremden (Weissen) fand er reine, weisse Erde, Sand, und so wurde denn dieser Mensch weiss. Dann kam er ins *pat ripo*, Land der Ägypter, da nahm er Nilschlamm und so entstand ein roter (brauner) Mensch. Endlich gelangte Čuok ins Land, wo jetzt die Schilluk wohnen, und da fand er viel *tado*, schwarze Erde, und so wurde denn der Schilluk und seine Stammesbrüder schwarz.

Andere Version: Als Čuok daran ging die Menschen zu schaffen, hatte er reine, weisse Hände, und so wurden denn die ersten Menschen, welche aus seiner Hand hervorgingen, weiss. Weil aber Čuok schnell machen wollte, reinigte er sich die Hände nicht mehr, und so wurde der Mensch im Lande der Ägypter nicht mehr so rein und weiss wie die vorhergehenden, er wurde rot (*quarr*). Endlich kam er mit beschmutzten Händen ins Schillukland, dazu noch die schwarze Erde, und so wurde der Bewohner dieses Landes schwarz.

Daher führt auch der Schilluk den Ausdruck im Munde: „Euer Gott muss recht weisse Hände gehabt haben, als er euch erschuf, weil ihr so gut seid." — Noch eine dritte Version welche die Verschiedenheit der Farbe dem Willen des Schöpfers zuteilt, erzählt man:

Čuok wollte von Anfang an alle Menschen gleichfarbig erschaffen. Dazu hatte er sich die weisse Farbe auserlesen. Doch wie er sich so auf der Erde umschaute und Überall bei Tieren und Pflanzen Verschiedenheit der Farbe sah, gefiel ihm das, und so entschloss er sich auch den Menschen verschiedenfarbig zu machen. Da er schon den Weissen erschaffen, ging er ins Land der Ägypter, nahm Nilschlamm und schuf einen braunen (*quarr*, eigentlich roten). Er kam auch hieher und schuf nun auch einen schwarzen, denn diese Farbe fehlte ihm noch. — „Aber," fügt der Schilluk hinzu, „wie es Verschiedenheit der Farbe bei den Schafen gibt, die einen weiss, die anderen rot, die anderen schwarz, aber doch alle Schafe sind, so ist auch der weisse, rote und schwarze Mensch einer gleich dem anderen." [11]

From a tale of the Peruvian Indians we learn that man was created afresh after the deluge. The deity made figures of clay to which he assigned distinguishing characteristics of the nations to be. He then endowed them with life and ordered them to pass under the ground. In the places where they came forth they founded the nations of the earth.[12]

The Zuñi of New Mexico tell how the Beloved Twain, sons of the Sun-father, conducted men from a cave in which they had been created to a second cave world. From it they "again led men upward, not all at once, but in six bands, to become the fathers of the six kinds of men, the yellow, the tawny gray, the red, the white, the black, and the mingled." [13]

[11] Hofmayr, P. W., "Religion der Schilluk," *Anthropos*, 6 (1911) : 128.

[12] Payne, E. J., *History of the New World Called America* (Oxford: At the Clarendon Press, 1892), I : 462.

[13] Judson, Katharine B., *Myths and Legends of California and the Old Southwest* (Chicago: A. C. McClurg & Co., 1912), pp. 19–23. According to another story, *ibid.*, p. 24, their "fathers were black, like the caves they came from."

A creation myth of the Achomawi Indians of northeastern California narrates the experiences of Coyote and Silver Fox at the beginning of the world, when all was water. They finally discovered solid ground, went ashore, built a sweat house, and lived in it. "They thought about making people; and after a time, they made little sticks of service-berry, and they thrust them all about into the roof of the house on the inside. And by and by all became people of different sorts, birds and mammals and fish, all but the deer, and he was as the deer are to-day."[14]

The folklore of the Ekoi, of southern Nigeria, accounts for the origin of the black and the white races in simple fashion, without the intervention of a god:

> In the beginning of things, Obassi had only one wife. These two were the first of all people. Before them neither man nor woman had ever been.
>
> In course of time the woman bore four children to her husband. Two were white and two black.[15]

From a Melanesian creation story we learn that light-skinned peoples are made from light-colored coconuts and the dark-skinned people from dark ones.[16]

A curious tale is told by the Herero of Hereroland (or Damara Land) in southwestern Africa.[17] According to it, the first man and woman were Mukuru and Kamumgarunga, who sprang from a holy tree. When children were born to them they slew an ox, but another woman — from some source and place unknown — came and took the brown-black liver for her children, who became black after eating it. Still another woman seized the lungs and blood for her children, who became red after partaking of them. Hence the Herero are now black and the Nama are red.[18]

[14] Dixon, R. B., "Achomawi and Atsugewi Tales," *The Journal of American Folk-Lore*, 21 (1908) : 159-169.

[15] Talbot, P. Amaury, *In the Shadow of the Sun* (London: Wm. Heinemann, 1912), p. 387.

[16] Dixon, R. B., *Oceanic Mythology* (Boston: Marshall Jones Co., 1916), p. 108. This work is Volume IX in the series "Mythology of All Races."

[17] Irle, I., *Die Herero: Ein Beitrag zur Landes-, Volks-, und Missionskunde* (Gütersloh: G. Bertelsmann, 1906), p. 76. The same story is told in simpler form by Andrew Lang, *Myth, Ritual and Religion* (New York: Longmans, Green and Co., 1913), I : 171: "Black people are so coloured, according to the Ovaherero, because when the first parents emerged from the tree [from which men are born] and slew an ox, the ancestress of the blacks appropriated the black liver of the victim."

[18] Since the ancestors of the Herero and the Nama fought for the hide of the ox, the story also explains the traditional hostility of these tribes.

CHANGES FROM AN ORIGINAL WHITE SKIN

The white race proudly assumes that the original color of all mankind was white. Since blackness and evil have ever been yokefellows, the explanations of the change from a white skin to black are uncomplimentary to the Negro. It is quite natural for Semitic lore to regard blackness as a penalty, and it was inevitable that such lore should be based upon the stories in the Old Testament.

According to one popular belief, Ham was punished with a dark skin because he broke the rule of chastity which obtained in the ark.[19] Another tradition states that a black skin was inflicted upon him because he laughed at his father, who had become uncovered in his sleep.[20]

Still another account makes Canaan, the son of Ham, the father of the black race. In Genesis ix.22 we are told that "Ham, the father of Canaan, saw the nakedness of his father . . .," but in verse 25 Noah says: "Cursed be Canaan; a servant of servants shall he be unto his brethren." In order to remove this apparent injustice to Canaan it has been explained that it was Canaan who saw the nakedness of Noah and that he told his father Ham about it. According to this version Noah's curse is more specific: "Cursed be Canaan and may God make his face black." [21]

It is said that the inhabitants of the Sudan believe their blackness to be due to Noah's curse, although it is also attributed to the great heat of the sun.[22]

[19] Grünbaum, Max, *Neue Beiträge zur semitischen Sagenkunde* (Leiden: E. J. Brill, 1893), pp. 86–87. See also Ginzberg, Louis, *The Legends of the Jews* (Philadelphia: The Jewish Publication Society of America, 1912), I: 166; Baring-Gould, S., *Legends of Old Testament Characters from the Talmud and Other Sources* (London: Macmillan and Co., 1871), I: 138.

[20] *Chronique . . . de Tabari*, I: 115 (translated by M. Hermann Zotenberg [Paris, 1887] from an abridged Persian version of the Arabic original) = p. 212 of the Arabic edition, *Annales quos scripsit Abu Djafar Mohammed ibn Djarir at-Tabari, cum aliis edidit M. J. De Goeje.* Prima Series I. Recensuit J. Berth. Lugd. Bat.: E. J. Brill, 1879–81. See also Grünbaum, *op. cit.*, p. 87; Dähnhardt, Oskar, *Natursagen; Eine Sammlung naturdeutender Sagen, Märchen, Fabeln, und Legenden* (Leipzig and Berlin: B. G. Teubner, 1907–12), I: 290. The basis for the story is Genesis ix.22.

[21] See Grünbaum, *op. cit.*, p. 86, where Semitic sources are given. In a Jewish tradition the visiting of the punishment upon Canaan has been accounted for in another way. On account of the blessing which God had bestowed upon Noah and his three sons as they issued from the ark Noah could do no injury to Ham himself, and hence punished him indirectly through his son. See Ginzberg, *op. cit.*, I: 168–169.

[22] Grünbaum, *op. cit.*, p. 87.

The Bible states that from the three sons of Noah the whole earth was overspread.[23] Readers have inferred from this that all racial differences developed among their descendants and have concluded that the children of Ham acquired their blackness from being burned by the sun. Jewish tradition does say that the land which fell to Ham was hot.[24]

The poet Ovid gives an etiological turn to the common Greek and Roman theory that the Ethiopians were burned black by the intense heat of the sun.[25] He picturesquely states that, when Phaethon was driving the chariot of the sun, the steeds got beyond his control and carried the sun near enough to the Ethiopians to draw the blood to the surface of their bodies and to turn them black.[26]

The idea that evil-doing may cause blackness of body is still current, as may be seen from a passage in a play by John Dos Passos, *The Garbage Man:*

> An up in de locust tree over our head a maukin' bird was singin', singin', comin' in at ma ears and goin' through ma body an warmin' it like whisky might, only sweeter and warmer. An' ah seemed to feel all de sins ah'd done, wit drinkin' whisky an' girls an' everythin' all come out black like ma skin tied up roun' me, an' dat sweet singin' lake angels pushin' 'em out o' me. An' ah seemed to hear a voice singin' in de maukin'; dat's why you's black, John Lincoln. You go git saved, John Lincoln, count o' yer sins.

CHANGES FROM AN ORIGINAL BLACK SKIN

The prophet Jeremiah asks whether an Ethiopian can change his skin.[27] Not all Negroes would answer this question in the negative, for their folklore gives many examples of changes from black skins to white. According to a Maryland Negro, "White people are descendants of Cain. All mankind was once black, but when the Lord asked Cain where Abel was, Cain turned white with fright and so remained." [28]

[23] Genesis ix.19.

[24] Ginzberg, *op. cit.*, I: 172. Isidore of Seville (*Etym.* 9.2.2) tells us that thirty-one peoples were descended from Ham, fifteen from Japhet, and twenty-seven from Shem. In *The Travels of Sir John Mandeville*, Chapter 24, it is said that Cham took Asia; Shem, Africa; and Japhet, Europe. See also the story recorded by Julia Peterkin, *Roll, Jordan, Roll* (New York: R. O. Ballou, 1933), p. 137.

[25] See page 53. [26] *Met.* 2.235–236. [27] Jeremiah xiii.23.

[28] Bergen, Fanny D., *Animal and Plant Lore* ("Memoirs of the American Folk-Lore Society," Vol. 7, 1899), p. 80, No. 915. See also Puckett, N. N., *Folk Beliefs of the Southern Negro* (Chapel Hill: University of North Carolina Press, 1926), pp. 4–5.

Seventy-five years ago a traveler in the ancestral land of the black man heard this same tale told with great elaboration. The following version of it is said to have come from the lips of a native preacher of Sierra Leone, where hatred of the white man was intense at that time:

My breddren, you see white man bad too much, ugly too much, no good. You want sabby how man like dat come to lib in the world? Well, I tell you. Adam and Eve dey colored people, very hansum; lib in one beautiful garden. Dere dey hab all things dat be good. Plantains, yams, sweet potatoes, foo-foo *palm wine* — he-igh, too much! Den dey hab two chilrum, Cain and Abel. Cain no like Abel's palaver; one day he kill'm. Den God angry, and he say, *Cain!* Cain go hide himself; he tink him berry claber. Heigh-heigh! God say again, Cain, you tink I no see you, you bush-nigger — eh? Den Cain come out, and he say, "Yes, massa, I lib here — what de matter, massa?" Den God say in one big voice like de tunder in de sky, "Where'm broder Abel?" Den Cain turn white all ober with fear — dat de first white man, breddren.[29]

According to another version of the same tragedy the whitening was a gradual process and was due to lingering and harassing fear:

. . . the story which you will often be told to account for the blackness and whiteness of men by Africans who have not been in direct touch with European, but who have been in touch with Muhammedan, tradition — which in the main has the same Semitic source — is that when Cain killed Abel, he was horrified at himself, and terrified of God; and so he carried the body away from beside the altar where it lay, and carried it about for years trying to hide it, but not knowing how, growing white the while with the horror and the fear; until one day he saw a crow scratching a hole in the desert sand and it struck him that if he made a hole in the sand and put the body in, he could hide it from God, so he did; but all his children were white, and from Cain came the white races, while Abel's children are black, as all men were before the first murder.[30]

The most delightful of these racial "just so" stories was told by Uncle Remus:

One night, while the little boy was watching Uncle Remus twisting and waxing some shoe-thread, he made what appeared to him to be a very curious discovery. He discovered that the palms of the old man's hands were as white as his own, and the fact was such a source of wonder that he at last made it the subject of remark. The response of Uncle Remus led to the earnest recital of a piece of unwritten history that must prove interesting to ethnologists.

[29] Reade, W. Winwood, *Savage Africa: Being the Narrative of a Tour in Equatorial, Southwestern, and Northwestern Africa* (New York: Harper and Brothers, 1864), p. 31. A not less circumstantial version of the way Cain turned white with fear is given by Witter Bynner in a poem called "Pallor," *The New Republic*, 44 (1925): 151–152. See also Burton, R. F., *Wit and Wisdom from West Africa* (London: 1865), p. 124.

[30] Kingsley, Mary H., *West African Studies* (London: Macmillan and Co., 1899), pp. 384–385.

"Tooby sho de pa'm er my han's w'ite, honey," he quietly remarked; "en, w'en it come ter dat, dey wuz a time w'en all de w'ite folks 'uz black — blacker dan me, kaze I done bin yer so long dat I bin sorter bleach out."

The little boy laughed. He thought Uncle Remus was making him the victim of one of his jokes; but the youngster was never more mistaken. The old man was serious. Nevertheless, he failed to rebuke the ill-timed mirth of the child, appearing to be altogether engrossed in his work. After a while he resumed:

"Yasser. Fokes dunner w'at bin yit, let 'lone w'at gwineter be. Niggers is niggers now, but de time wuz w'en 'uz all niggers tergedder."

"When was that, Uncle Remus?"

"Way back yander. In dem times we 'uz all un us black; we 'uz all niggers tergedder, en cordin' ter all de 'counts w'at I years folks 'uz gittin 'long 'bout ez well in dem days ez dey is now. But atter 'w'ile de news come dat dere wuz a pon' er water some'rs in de naberhood, w'ich ef dey'd git inter dey'd be wash off nice en w'ite, en den one un um, he fine de place en make er plunge inter de pon', en come out w'ite ez a town gal. En den, bless grashus! w'en de fokes seed it, dey make a break fer de pon', en dem w'at wuz de soopless, dey got in fus' en dey come out w'ite; en dem wa't wuz de nex' soopless, dey got in nex', en dey come out merlatters; en dey wuz sech a crowd un um dat dey mighty nigh use de water up, w'ich w'en dem yuthers come 'long, de morest dey could do wuz ter paddle about wid der foots en dabble in it wid der han's. Dem wuz de niggers, en down ter dis day dey ain't no w'ite 'bout a nigger 'ceppin' de pa'ms er der han's en de soles er der foot." [31]

The little boy seemed to be very much interested in this new account of the origin of races, and he made some further inquiries, which elicited from Uncle Remus the following additional particulars:

"De Injun en de Chinee got ter be 'counted 'long er de merlatter. I ain't seed no Chinee dat I knows un, but dey tells me dey er sorter 'twix' a brown en a brindle. Dey er all merlatters."

Did the Uncle Remus story come in whole or in part from Africa? The following tale from the French Congo is worth quoting in connection with it:

It was in the beginning, and four men were walking through a wood. They came to a place where there were two rivers. One river was of water, clear as crystal and of great purity; the other was black and foul and terrible to the taste. And the four men were puzzled as to which river they should cross; for, whereas the dirty river seemed more directly in their way, the clear river was the most pleasant to cross, and perhaps after they had crossed it they might regain their proper path. The men, after some consultation, thought that they ought to cross the black river, and two of them straightway crossed it. The other two, however, scarce touched and tasted the water than they hesitated and returned. The two that had now nearly crossed the river called to them and urged them to come, but in vain. The other two had determined to leave their companions, and to cross the beautiful and clear river. They crossed it, and were astonished to find that they had become black, except just those parts of them that had touched

[31] Harris, Joel Chandler, *Uncle Remus: His Songs and His Sayings* (New York: D. Appleton and Co., 1920), pp. 163–165.

the black river, namely, their mouths, *the soles of their feet, and the palms of their hands.* The two who had crossed the black river, however, were of a pure white colour. The two parties now travelled in different directions, and when they had gone some way, the white men were agreeably surprised to come across a large house containing white wives for them to marry; while the black men also found huts, or shimbecs, with black women whom they married. And this is why some people are white and some black.[32]

White adventurers and explorers in Africa still meet with naïve explanations of their color. One of them was told by his cannibal servant that the white man is white because of some disease.[33] Needless to say, the information imparted a sense of security to the expedition.

Tribes in the interior of New Guinea called "ghosts from the sea" the first white adventurers whom they saw.[34] A member of another expedition says of these primitive people: "According to their notions the outside world was a world of spirits, and many of them took us, with our white skins, for ghosts of their ancestors. Only at our coming did they learn of a world of men beyond their mountain walls." [35]

In both Africa and Australia there has flourished, sometimes with amusing results, the superstition that white men are reincarnations of black men:

The belief in the new human birth of the departed soul, which has even led West African negroes to commit suicide when in distant slavery, that they may revive in their own land, in fact amounts among several of the lower races to a distinct doctrine of an earthly resurrection. One of the most remarkable forms which this belief assumes is when dark-skinned races, wanting some reasonable theory to account for the appearance among them of human creatures of a new strange sort, the white men, and struck with their pallid deathly hue combined with powers that seem those of superhuman spiritual beings, have determined that the manes of their dead must have come back in this wondrous shape. The aborigines of Australia have expressed this theory in the simple formula, "Blackfellow tumble down, jump up Whitefellow." Thus a native who was hanged years ago at Melbourne expressed in his last moments the hopeful belief that he would jump up Whitefellow, and have lots of sixpences. The doctrine has been current among them since early days of European intercourse, and in accordance with it they habitually regarded the Englishmen as their own deceased kindred, come back to their country from an attachment to it in a former life. Real or imagined likeness completed the delusion, as when Sir George Grey was hugged and wept over by an old woman who found in him a son she had lost, or when a

[32] R. E. Dennett, *Notes on the Folklore of the Fjort* (*French Congo*), ("Publications of the Folk-Lore Society," Vol. 41), pp. 101 102. The italics are mine.

[33] *The Detroit News*, "Features," July 15, 1928.

[34] *Ibid.*, "Magazine Section," Oct. 21, 1924, p. 8.

[35] *The New York Times Magazine*, Sept. 16, 1924, p. 4.

convict, recognized as a deceased relative, was endowed anew with the land he had possessed during his former life. A similar theory may be traced northward by the Torres Islands to New Caledonia, where the natives thought the white men to be the spirits of the dead who bring sickness, and assigned this as their reason for wishing to kill white men. In Africa, again, the belief is found among the Western negroes that they will rise again white, and the Bari of the White Nile, believing in the resurrection of the dead on earth, considered the first white people they saw as departed spirits thus come back.[36]

TALES AND LORE FROM THE FAR EAST

The curiosity of Asiatics toward persons and races of different colors has been exemplified by quotations at the beginning of this paper, but aside from these passages and Semitic tales (pp. 42 43) I have collected only a little lore from Asia.

We have seen that the change from black to white has been explained as due to fear (p. 44). According to a paragraph in a popular magazine,[37] the Sultan of Selangor and his wife, who lived in constant dread of automobiles while they were visiting England in 1936, "thought at first that it must be fright at the terrible traffic which made English girls so pale." Rather recently (1936?) the whiteness of English men has been quite differently explained by natives on the Assam–Burma border, where some slaves whom a British punitive expedition had rescued from tribes which practiced human sacrifice were terrified by the "strangers of a curiously pale, 'unripe' color and bewildering habits." [38]

The Santal Parganas of India say that mankind was divided into twelve races because of different choices of food which their ancestors made at a banquet.[39]

Negro and American Indian explanations of the colors of Asiatics are given elsewhere in this paper (pp. 45, 53).

INDIAN TALES OF THE ORIGIN OF WHITE, BLACK, AND RED SKINS

We have seen how the white man and the black man both take it for granted that the color of his own skin was the original color of

[36] Tylor, E. B., *Primitive Culture* (New York: G. P. Putnam's Sons, 1920), II: 5–6. The American Indian has been known to call Europeans spirits. See Parkman, Francis, *La Salle and the Discovery of the Great West* (Boston: Little, Brown, and Co., 1894), pp. 254–255.

[37] *Time*, 28 (1936): 22.

[38] *The Illustrated London News*, 100 (1937): 1200.

[39] Bompas, C. H., translator, *Folklore of the Santal Parganas* (London: D. Nutt, 1909), p. 404.

all mankind and how, in general, each tries to explain only one deviation from it. Naturally the Indian had tales which accounted for the diversification and scattering of tribes,[40] but when his land was disturbed by the intrusion of men from beyond the sea and he was brought face to face with striking contrasts in the colors of the human body, he created others to explain, often to the disparagement of the new arrivals, how whiteness, blackness, and redness were acquired. In the most characteristic of these tales whiteness and blackness are attributed to mistakes or to some unfortunate experience, and red is the perfect or culminating color. The threefold picturesqueness of such stories would impress them upon the hearer, and doubtless it increased the probability of their being remembered and recorded. I shall quote first the simpler and less interesting accounts of the creation of man.

The Penobscots thus explain the blackness of the Negro: "There was a boy who laughed constantly at his parents. Every time they said anything he would laugh till he was black in the face. So he became black and the father of the negro race. They are always laughing and showing their teeth." [41]

A fragment of a tale of the northern Mewuk Indians of California explains how they got their dark complexion:

> When water covered the world only the top of the highest mountain rose above it. The people had climbed up on this mountain, but could find no food and were starving. They wanted to go off and get something to eat. When the water went down all the ground was soft mud. After a while the people rolled rocks down to see if the mud were hard enough to hold them. When the rocks stayed on top, the people went down to search for food.
>
> But the mud was not hard enough to hold them and they sank out of sight, leaving deep holes where they had gone down. Then *Kah'-kah-loo* the Ravens came and stood at the holes, one at each hole where a man had gone down. After a while, when the ground hardened, the Ravens turned into people. That is the reason the Mewuk are so dark.[42]

In a Choctaw myth the Great Spirit causes warriors of different colors to emerge from the summit of a smoking mountain and to depart in four directions: a fair-complexioned man to the north; a

[40] See, for example, a Choctaw myth recorded by D. I. Bushnell, Jr., *The Choctaw of Bayou Lacomb, St. Tammany Parish, Louisiana* (Smithsonian Institution, Bureau of American Ethnology, Bulletin 48), p. 30.

[41] Speck, Frank G., "Penobscot Tales and Religious Beliefs," *Journal of American Folk-Lore*, 48 (1935) : 94.

[42] Merriam, C. H., *The Dawn of the World: Myths and Weird Tales Told by the Mewan Indians of California* (Cleveland: Arthur H. Clark Co., 1910), p. 101.

slightly darker man, a Chickasaw Indian, to the west; a copper-colored Choctaw to the south; and a much darker man to the east. They established the white, red, and black races in the lands to which they went.[43]

An explanation of the origin of the redness and the whiteness of races is to be found in a creation story told by an old Indian from the Pueblo of Acoma,[44] a member of a party of Indians who were visiting the Bureau of American Ethnology in Washington, D.C., in 1928.

In the beginning two female children were born under ground at a place called Cipapu. After they had grown up a spirit, Tsitctīnăkō, spoke to them and taught them. When they finally reached the world of light, they were told by the spirit to pray with their own and their clan names, so that the sun would know and recognize them.

When the sun appeared, it was too bright for Iă'tīk°, and it hurt her eyes. She wondered if Nao'tsiti's eyes hurt her too, so she put her head down and sideways, letting her hair fall, and looked at Nao'tsiti. By doing this the light did not strike her square in the face, and her hair caused a little reddish shade. Tsitctīnākō said, — "Iă'tīk°, the sun has not appeared for you. Look at Nao'tsiti; see how strongly the light is striking her. Notice how white she looks." And although Iă'tīk° turned to the sun, it did not make it as white as Nao'tsiti, and Iă'tīko's mind was slowed up, while Nao'tsiti's mind was made fast.[45]

Later on Nao'tsiti bore two children, which she had conceived as the rain fell on her while she was lying upon her back. When a feeling of estrangement developed between the sisters, Nao'tsiti took one of her children and went to the East, where, it is implied, she became the ancestress of the white race. There is, however, a group of creation stories which make it clear that two sisters became the founders of the white and the red races.[46]

The Indians had stories which recall the one told by Uncle Remus (see p. 44). A Creek tale, for example, runs as follows:

Three Indians were once out hunting. One went after water and found a nice hole of water but was afraid to drink. Another went down to it, dipped his fingers in, and said, "It is good. Let us go into it." So he dived in and came out. When he came out he was white. From him came the white people. The second

[43] Culbertson, James, "Choctaw Fables," *Folk-Say, A Regional Miscellany*, No. 1 (1929), 25–26.

[44] "Acoma is the westernmost of the Keresan-speaking group of Rio Grande Pueblos in New Mexico, situated with Laguna at some distance to the south-west of the main group." See page 370 of article cited in the next note.

[45] Forde, C. Daryll, "A Creation Myth from Acoma," *Folk-Lore*, 41 (1930): 370–387. Quotation on page 376.

[46] *Ibid.*, p. 370.

dived in and came out darker because the water was somewhat roily. From him came the Indians. The third dived in and came out black because the water was now very roily. From him came the negroes.[47]

A somewhat similar story, but obviously influenced by missionary teaching, has been collected among the Biloxi, a tribe which formerly dwelt on the coast of Mississippi:

Kuti Mandkce, the One Above, made people. He made one person, an Indian. While the Indian was sleeping, he made a woman. Then the One Above went away to find food for the man and woman.

After he left, something was standing there upright. It was a tree. A person said, "Why do you not eat the fruit of this tree? I think he made it for you to eat."

So the woman pulled off some fruit and stewed it and she and the Indian ate it. Shortly after, the One Above returned. Now he had gone away to find food for them. When he found they had stewed this fruit, he was very angry. He said, "Work for yourself. Find your own food, else you shall be hungry."

When the One Above had been a long time gone, he sent back a letter to the Indians. But the Indians did not receive it, because the Americans took it. That is why Americans know how to read and write.

Now after the letter came, the people found a very clear stream of water. The American found it first and lay down in it; therefore he is very white all over. Next came the Frenchman, but the water was not so clear. Then came the Indians; therefore Indians are not of light complexion, because they did not find the water when it was clear. Afterwards came the Spaniard, and he was not white, because the water had become very muddy.

Some time after the Negro was made. The One Above thought he should attend to work, so he made the Negro's nose flat. And by this time the water was very muddy, and the stream was very low. So the Negro washed only the palms of his hands. Therefore Negroes are very black except on the palms of their hands.[48]

In a Carib version it is to clean and soiled moulds rather than to water that the colors of the races of mankind are attributed:

. . . Then the Great Spirit — Makanaima — made a large mould, and out of this fresh, clean clay, the white man stepped. After it got a little dirty the Indian was formed, and the Spirit being called away on business for a long period the mould became black and unclean, and out of it walked the negro.[49]

Indian lore, too, represents man as having been created from the ground, as may be seen from a Salishan tale, collected at Okanogan

[47] Swanton, J. R., *Myths and Tales of the Southeastern Indians* (Smithsonian Institution, Bureau of American Ethnology, Bulletin 88), p. 75. Swanton records a simpler version of this story on page 74.

[48] Judson, Katharine B., *Myths and Legends of the Mississippi Valley and the Great Lakes* (Chicago: A. C. McClurg & Co., 1914), pp. 12–13.

[49] Boddam-Whetham, J. W., *Roraima and British Guiana* (London: Hurst and Blackett, 1879), p. 172.

in British Columbia, in which the Chief (or God) is pictured as fashioning the principal races:

. . . Thus the first Indians were made by him from balls of red earth or mud, and this is why we are reddish-colored. Other races were made from soil of different colors. Afterwards some of these different races met at certain points and intermingled, and thus the intermediate shades of color have arisen. As red earth is more nearly related to gold and copper than other kinds of earth, therefore the Indians are nearer to gold, and finer than other races.[50]

A Senecan story of the creation of man from earth is far more elaborate:

God at first created the sun and the moon. One day while walking about on the earth, becoming lonely, he said, "I will make a human being to keep me company." He held his way until he came to an uprooted hemlock, which had raised a great pile of earth with its upturned roots. Now, the roots of the hemlock are very numerous and slender and are covered with tufted rootlets for, as the tree grows on thin, pale, sandy soil, it needs many feeders to provide the necessary sustenance. God made a human being from the earth piled up among the roots of this tree. There were so many fibers in this earth that the human being was seemingly hairy, and the soil was so poor and light-colored that he had a pale, sickly complexion. God breathed on him and he stood up and walked. Then God looked at him from behind the roots of the tree, but being not pleased with his creation, he resolved that he would try again.

God soon came to a walnut tree lying uprooted, which had pulled up with its roots a mound of black earth. From this earth God made another human being. As he looked at him, he saw that, being black, he had too much color. So God was not satisfied with this piece of work, either.

Going on farther, he came at last to an uprooted sugar maple. There the earth had a fine deep color; so out of this God made the third human being, whose body was smooth and firm and of a full rich tint. And God, pleased with his looks, said, "He will do; he looks like me." This last human being was an Indian; thus the Indian was the native human being.[51]

According to the Cree Indians, whiteness, blackness, and redness among the races are due to the application of different degrees of heat during a trial-and-error method of creating a perfect man, the red one:

When Great One made mankind, he first made an earth oven. Then he modeled a man of clay and put him in to bake. He was not baked enough and came out white. Great One tried again, but this time he baked the man too long. He came out black. The third time Great One baked the man just the correct time, and he came out red. That is the reason why different races have different colors.[52]

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[50] Boas, Franz, *Folk-Tales of Salishan and Sahaptin Tribes* ("Memoirs of the American Folk-Lore Society," Vol. XI [1917]), p. 84.

[51] Curtin, J., and Hewitt, J. N. B., "Seneca Fiction, Legends, and Myths," *Annual Report of the Bureau of American Ethnology*, 32 (1918) : 168–169.

[52] Judson, Katharine B., *Myths and Legends of British America* (Chicago: A. C. McClurg & Co., 1917), p. 109.

The Seminoles had a remarkably similar picture of the genesis of the three great races with which they were familiar. They "believed that man was originally formed from the clay; that the Great Spirit submitted his creation to the influence of fire, but that his ignorance of the degree of heat necessary to give consistency caused the first batch to be overbaked, black, and crusty; these were the aborigines of the negro race. Again the Creator essayed, but endeavoring to avoid the error of the former attempt, he plunged into another, that of applying too little fuel. They were in consequence but half baked, of a pale ash color. These were our first parents. But in the third and last effort the Great Master created perfect models, both in shape and color, producing to the world the founders of the Indian tribes." [53]

A story that resembles this one, perhaps a variant of it, was employed by the Seminole chieftain Neamathla on a formal occasion. In the treaty of Moultrie Creek, concluded on September 18, 1823, provision was made for the establishment of a school among the Seminoles. The chiefs were unwilling to expose their children to the white man's methods of education, and upon Neamathla fell the delicate office of communicating their decision to the governor of Florida. In his speech he made use of the Seminole myth of the creation of man: [54]

> . . . Then the Master of Life said, we will make man. Man was made; but when he stood up before his Maker he was *white!* The Great Spirit was sorry: he saw that the being he had made was pale and weak; he took pity on him, and therefore did not unmake him, but let him live. He tried again, for he was determined to make a perfect man; but in his endeavor not to make another white man, he went into the opposite extreme, and when the second being rose up, and stood before him, he was *black!* The Great Spirit liked the black man less than the white, and he shoved him aside to make room for another trial. Then it was that he made the *red man;* and the red man pleased him.

A variation of this myth may be found in the works of Washington Irving. According to him a Seminole chieftain thus addressed the governor of Florida:

> My brother, we have been thinking over the proposition of our Great Father at Washington, to send teachers and set up schools among us. We are very thankful for the interest he takes in our welfare; but after much deliberation, have decided to decline the offer. What will do very well for white men, will not do for red men. I know you white men say we all come from the same father and mother, but you are mistaken. We have a tradition handed down from our fore-

[53] *Narrative of a Voyage to the Spanish Main in the Ship "Two Friends"* (London, 1819), summarized by Swanton, p. 75, as cited in note 47.

[54] McKenney, Thomas L., *History of the Indian Tribes of North America* (Philadelphia: Rice, Rutter & Co., 1870), I: 82–83.

fathers, and we believe it, that the Great Spirit, when he undertook to make men, made the black man; it was his first attempt, and pretty well for a beginning; but he soon saw he had bungled; so he determined to try his hand again. He did so, and made the red man. He liked him much better than the black man, but still *he* was not exactly what he wanted. So he tried once more, and made the white man; and then he was satisfied. You see, therefore, that you were made last, and that is the reason I call you my youngest brother.[55]

In this form the myth fails to show the pride of race and the self-sufficiency which help to give rise to etiological tales. If the turn of phrase at the end is clever, it is a white man's cleverness — and distortion.

There was not much occasion for Indian tribes to speculate about the colors of the skins of Orientals, but I have found one explanation in the lore of the Cochiti. According to this tale, people who survived the flood were called "last year's crop people." "They were yellow like last year's corn, and their hair was curled up in queues on their heads like last year's husks." [56] The narrator of the story identified them as Chinese and Japanese.

GREEK AND ROMAN LORE AND THEORIES

As the Greeks and the Romans traveled the length and breadth of the ancient world on errands of trade and conquest they, too, speculated about the various colors of the races of mankind. Although there has survived only one etiological story which they created about the color of man, the myth about Phaethon (see p. 43), their views are worthy of inclusion in this paper. The Greeks tried to make a scientific approach to the subject, but some of their ideas were folklore to begin with.

Both classical nations explain the darkness of the peoples of India and Africa as due to their having been scorched or burned because of their nearness to the sun and because of the dryness of the atmosphere.[57] The name Ethiopian (Αἰθίοψ) is itself mute testimony

[55] Irving, Washington, "Origin of the White, the Red, and the Black Men," in *Wolfert's Roost and Other Papers.*

[56] Benedict, Ruth, *Tales of the Cochiti Indians* (Smithsonian Institution, Bureau of American Ethnology, Bulletin 98), p. 3.

[57] A few references to typical passages may be given: Aesch., *Prom. Vinctus* 808–809; Plut., *Mor.* 838 A; Lucretius 6.721–722; Tibullus 2.3.55–56; Ovid, *Met.* 2.235–236; Manil., *Astron.* 4.723–730, 758; Lucan, *Phars.* 10.131, 221–222; Pliny, *Nat. Hist.* 2.189; Hyg., *Fab.* 154; Macrob., *Somn. Scip.* 2.10.11; Serv. on Verg., *Aen.* 4.481; Isid., *Etym.* 14.5.14. We are told that the names "Mauri" and "Mauretania" originated from the blackness of people and that their color was due to exposure to heat. See Manil., *Astron.* 4.729–730; Isid., *Etym.* 9.2.122.

to Greek ideas, for it is composed of two words (αἴθω + ὄψ) which mean "Burnt Face." [58] One writer does hold, however, that the Indians were black by nature rather than from the heat of the sun.[59]

The conflicting opinions of the best-informed ancients in regard to the cause of blackness in man are well set forth by Strabo:

. . . But Onesicritus believes that rain-water is the cause of the distinctive differences in the animals; and he adduces as evidence that the colour of foreign cattle which drink it is changed to that of the native animals.[60] Now in this he is correct; but no longer when he lays the black complexion and woolly hair of the Aethiopians on merely the waters and censures Theodectes, who refers the cause to the sun itself, saying as follows: "Nearing the borders of these people the Sun, driving his chariot, discoloured the bodies of men with a murky dark bloom, and curled their hair. . . ." But Onesicritus might have some argument on his side; for he says that, in the first place, the sun is no nearer to the Aethiopians than to any other people, but is more nearly in a perpendicular line with reference to them, and therefore it is incorrect to say, "Nearing the borders . . . the sun," since the sun is equidistant from all peoples; and that, secondly, the heat is not the cause of such a discoloration, for it does not apply to infants in the womb either, since the rays of the sun do not touch them. But better is the opinion of those who lay the cause to the sun and its scorching, which causes a very great deficiency of moisture on the surface of the skin. And I assert that it is in accordance with this fact that the Indians do not have wholly woolly hair,[61] and also that their skin is not so unmercifully scorched, I mean the fact that they share in an atmosphere [62] that is humid. . . .[63]

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[58] An interesting addition to our knowledge of the etymology of the word Αἰθίοψ has been made by W. H. Worrell, *The Coptic Manuscripts of the Freer Collection* (University of Michigan Studies, Humanistic Series, Vol. X), p. 355.

[59] Ctesias, ap. Phot., *Bibliotheca*, p. 46 of I. Bekker's edition (Berlin, 1824).

[60] There are many references to the power of water in certain places to change the color of animals, e.g. Strabo 6.1.13, 10.1.14; Aristotle, *Hist. Anim.* 3.12, 519a 18; *idem*, *Ausc. Mirab.* 169–170; Aelian, *De Nat. Anim.* 8.21, 12.36; Antig., *Hist. Mirab.* 78 (84), 134 (149); Pliny, *Nat. Hist.* 2.230, 31.13; Seneca, *Nat. Quaest.* 3.25.2–3; Vitruvius 8.3.14; Isid., *Etym.* 13.13.5; Solinus 7.27, 33.1.

[61] See also Strabo 6.1.13. Pliny, *Nat. Hist.* 31.14, says that men who drink from the Sybaris River become darker and have curly hair, whereas those who drink from the Crathis acquire a lighter complexion and have straight hair. Cf. Ovid, *Met.* 15.317–318:

> Quodque magis mirum, sunt qui non corpora tantum
> Verum animos etiam valeant mutare liquores.

Aristotle, *Probl. Ined.* 2.72, contrasts with the curly hair of the Ethiopians that of a people farther north, the Scythians, who, he says, have straight hair. He attributes the crispness of the hair of the Ethiopians to their living near the sun. Cf. Pliny, *Nat. Hist.* 2.189: ". . . Aethiopas vicini sideris vapore torreri adustisque similes gigni, barba et capillo vibrato, non est dubium. . . ."

[62] Strabo 15.1.13 states that the color of the people of southern India resembles that of the Ethiopians and likewise gives the humidity in the atmosphere as the reason for the failure of their hair to curl.

[63] 15.1.24 (H. L. Jones' translation in the Loeb Classical Library).

The fair complexions of races in the north are attributed by Vitruvius to abundance of moisture and coolness of the atmosphere.[64] Isidore thinks that differences in the color of the skin, in the size of the body, and in temperament are all caused by variation in climate.[65] Even the stars are charged with being the cause of the different colors and dispositions of the races of mankind.[66]

MODERN BELIEFS

For many centuries not much advance was made upon Greek and Roman theories in regard to the reason for the different colors of the races. In 1582 an author who was well informed for his day wrote as follows:

> What then is the efficient cause of this colour [blackness]? It can be no otherwise, but either the businesse of heaven or of the earth, or perchance a certain unknowen propertie of the soyle, or a certayne reason hidden properlie in Nature unknowen to man, or altogether unperceived.
>
> But these things I leave to be considered of the searchers out of the nature of things.[67]

Within a century after these words had been written Sir Thomas Browne summarized what was known about the cause of blackness in Negroes.[68] Since his works are readily available in large libraries I shall content myself with the quotation of but one sentence: "Which whoever strictly enquires, shall find no less of darkness in the cause, than in the effect it self." [69]

The most interesting lay speculations which I have seen upon this general subject were made over a century ago by a missionary who spent eighteen years in Paraguay. Some of them are as follows:

> I have often wondered that the savage Aucas, Puelches or Patagonians, and other inhabitants of the Magellanic region, who dwell nearer to the South Pole, should be darker than the Abipones, Mocobios, Tobas, and other tribes, who live in Chaco, about ten degrees farther north, and consequently suffer more from the heat. May not the difference of food have some effect upon the complexion? The Southern savages feed principally upon the flesh of emus and horses, in which the plains abound. Does this contribute nothing to render their skin dark?

[64] 6.1.3.

[65] 9.2.105.

[66] Firm. Mat., *Math.* 1.3.1, 1.5.6, and Manil., *Astron.* 4.712–730.

[67] Batman, Stephen, *Batman uppon Bartholome, His Booke De Proprietatibus Rerum, Newly corrected, enlarged, and amended . . .* (London, 1582), p. 251.

[68] *The Works of Sir Thomas Browne*, edited by Geoffrey Keynes (London: Faber and Gwyer, 1928), III : 231–247.

[69] *Ibid.*, p. 232.

What, if we say that the whiteness of the skin is destroyed by very severe cold, as well as by extreme heat? Yet if this be the case, why are the inhabitants of Terra del Fuego more than moderately white: for that island is situated in the fifty-fifth degree of latitude, at the very extremity of South America, hard by the Antarctic Pole? May we not suppose that the Southern nations derive their origin from Africa, and brought the dark colour of the Africans into America? [70]

CONCLUSION

Motifs for Etiological Stories

In the natural world there are animals and plants which have striking shapes, colors, markings, habits, traits, and characteristics. Curiosity about such distinctive things in the animal and vegetable kingdoms leads savages and other simple-minded people to create "just so" stories to explain how they were acquired, for it is naïvely assumed that they were not original.[71] In this general classification are included the tales fabricated to account for variation in the colors of the races of mankind.

The first step in the creation of an etiological story is the noticing of a prominent or a distinctive characteristic; the second is reflection upon the cause of it. In the introduction to this paper there appear three quotations which reveal the intense interest manifested by unsophisticated peoples in strangers of a different color. With a little play of folk imagination their curiosity might have found expression in an etiological tale. It may actually have done so after they secured leisure for speculation. Doubtless the Indians applied the name "palefaces" to the queer people from abroad long before they invented their numerous explanations of whiteness.

A traveler in a foreign country naturally notes differences in customs and in ways of doing things. The less reflective he is the more he is inclined to regard the manners of his own country as the standard and those of the foreign land as departures from the normal. In much the same way the naïve people among whom etiological stories originate generally assume, on coming in contact with another race, that their own characteristics are original and normal and that the foreigner's have been acquired. How easy it is to believe such

[70] *An Account of the Abipones, an Equestrian People of Paraguay*, from the Latin of Martin Dobrizhoffer (London: 1822), II: 9–10.

[71] I have given much lore of this kind in an article called "How and Why: 'Just So' Mythology in Ovid's *Metamorphoses*," *The Classical Journal*, 15 (1920): 260–278.

things is shown by an experience of an American woman among Japanese girls:

> You would smile to see their curiosity concerning me. They think my waist is very funny and they measure it with their hands and laugh aloud. One girl asked me in all seriousness if I had pieces cut out of my sides, and another wanted to know if my hair used to be black. You see in all this big city I am the only person with golden tresses, and a green carnation would not excite more comment.[72]

These girls could have made two good etiological stories about this strange lady by explaining how or why her waist had been trimmed to its remarkable thinness and what had caused her hair to change its color.

A Negro who distinguishes between "Negro" and "nigger" says that "A nigger's a mean white man." Here, again, is potential material for a tale. With the specification of an act of meanness which caused a white man to turn black, these few words could be amplified into a story.

Even among highly civilized peoples we find material capable of being elaborated by a plastic mind. At the beginning of the World War the Germans derisively called the Canadians "White Ghurkas," [73] but they went a little farther on the road to an etiological story when they dubbed American Negro soldiers "Smoked Yankees." Here it is humorously postulated that the Negroes had once been white and that they had been smoked black. The only thing lacking is an incident or an accident to account for the smoking.

The name "Black Semites" as used to designate the Danakil of French Somaliland [74] might also have been employed as a starting point for an interesting tale.

In a whimsical moment it occurred to Herman Melville that soot caused the blackness of Africans, and he elaborated the idea:

> I do deem it a most meaning thing, that that old Greek, Prometheus, who made men, they say, should have been a blacksmith, and animated them with fire; for what's made in fire must properly belong to fire: and so hell's probable! How the soot flies! This must be the remainder the Greek made the Africans of.[75]

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[72] Little, Frances (pseudonym of Mrs. Fannie Caldwell Macaulay), *The Lady of the Decoration* (New York: The Century Co., 1906), p. 31.

[73] Peat, Harold R., *Private Peat* (Indianapolis: The Bobbs-Merrill Co., 1917), p. 115.

[74] *National Geographic Magazine*, 60 (1931) : 364.

[75] *Moby Dick*, Chapter 107.

This fanciful explanation of a change in color is not less strange than others made in all sincerity. In Arabia the whiteness of strangers has been variously attributed to their rubbing soap into themselves, to their living entirely on milk, and to their dwelling in houses.[76] These theories are as logical as those advanced by the Greeks.

Use of Material Already in Existence

Doubtless some etiological stories were created out of whole cloth by a single individual, but in a number of them the final touch is merely a happy elaboration of material already available in the form of a basic idea or a superstition. The folk imagination puts the capstone on the structure. In the simplest stories a deity is responsible for the colors of the different races, just as he is responsible for the creation of man and of all life, with its countless attributes. Other stories, however, are somewhat more involved.

In folklore the association of a black skin with evil is almost as natural as that of blackness and evil. Even Topsy, the dullard Negro pickaninny of *Uncle Tom's Cabin*, recognizes the futility of trying to overcome the handicap of a black exterior, for in answer to Eva's exhortation to her to be good she replies: "Couldn't never be nothin' but a nigger, if I was ever so good. If I could be skinned, and come white, I'd try then." Christianity, however, found a way to make black souls white. The Latin Church Fathers compare with Ethiopians those whose souls had been black before conversion: "Aptly do we describe as Ethiopians sinners who had previously been hideous with darkened hearts";[77] "Ethiopians are black. Those are called to the Faith who were black."[78]

Inasmuch as the Ethiopians were supposed to have been descended from Ham[79] and inasmuch as Ham had been guilty of wrongdoing,

[76] Van der Meulen, D., and Wissman, H. von, *Hadramaut; Some of Its Mysteries Unveiled* (Leyden: E. J. Brill, 1932), pp. 23–24. See also the quotation from the first of these authors, pp. 37–38.

[77] Cassiodorus, *In Psalterium*, 73.13 (Migne, *Patrol. Lat.*, 70.551): "Aethiopes bene peccatores advertimus qui ante fuerant tenebrosa mente deterrimi. . . ."

[78] Augustine, *In Psalmum*, 73.16 (Migne, *Patrol. Lat.*, 36.938): "Aethiopes enim nigri sunt. Ipsi vocantur ad fidem qui nigri fuerant." Cf. Ambrose, *De Paradiso*, 3.16 (Migne, *Patrol. Lat.*, 14.281): "Quid autem abiectius nostro corpore? Quid tam Aethiopiae simile quod etiam nigrum est quibusdam tenebris peccatorum?"

[79] A rather interesting Latin record of this tradition is Isidore, *Etym.* 9.2.127: "Aethiopes dicti a filio Cham, qui vocatus est Chus, ex quo originem trahunt. Chus enim Hebraica lingua Aethiops interpretatur." See also *ibid.*, 9.2.39.

what was more natural than to ascribe their blackness to the misdeeds of their ancestors? In antiquity curses were popularly endowed with great power and could cause more evils than they do today, so that the idea that a curse could inflict blackness put no strain upon the imagination.

The tradition that Ham was punished with a dark skin because he broke the rule of chastity in the ark (see p. 42) is merely a specialized version of a superstition which was widespread in ancient lore. In time of danger and during perilous undertakings continence was a precautionary measure. St. Ambrose was familiar with this idea from his pagan contacts, and undoubtedly believed in it, so far as the ark was concerned, for he enlarges upon it in his work *De Noe et Arca*.[80] Achilles Tatius often heard from experienced seamen that chastity should be observed on ship, either because the ship was holy or because intercourse endangered it.[81] The orator Antiphon [82] tells us that those who embark with unclean hands or otherwise contaminated cause their own destruction as well as the death of worshipers of the gods.[83] It must have been an ultrapious person who first associated the superstition and Ham. We are told by Hesiod that the gods bring trouble upon him who crosses a river with hands unwashed of wickedness.[84] Is this the earliest and simplest form of the superstition?

Not even the resourceful Ovid, whose naïveté sometimes seems real rather than assumed, created the etiological part of the Phaethon story independently (see p. 43). Others before him had explained that the Sun had blackened the bodies of the Ethiopians by driving his chariot near the borders of their land,[85] and it is not impossible

[80] 21.76 (Migne, *Patrol. Lat.*, 14.397).

[81] 5.16.

[82] *Orationes*, 5.82.

[83] An American example of this superstition is given by Emelyn E. Gardner, *Folklore from the Schoharie Hills, New York* (Ann Arbor: University of Michigan Press, 1937), p. 79: "Dr. Brink was once called to a ship on the Hudson that wouldn't work. He said: 'There is somebody with evil in him aboard this ship.' He repeated this until finally a young man confessed that he had gotten a girl into trouble and then refused to marry her because he didn't love her. Dr. Brink said that he must leave the ship or be thrown overboard. He refused to leave, so they threw him overboard. And the ship was all right. It never refused to work again."

[84] *Works and Days*, 740–741.

[85] Theodectes, for instance, had done so. See the passage quoted from Strabo on page 54.

that Ovid found in older versions of his tale the conceit that Phaethon himself was guiding the car when it approached the country of the Ethiopians.

The tale told by the Florida Negro (p. 39) may well have arisen from the suggestion of an actual misinterpretation of "Git back" as "Git black." Momentous consequences have resulted from misunderstandings equally trivial.

A clever Negro who heard white persons speak of turning white [86] through fear might easily create tales about black men turning white (see, for example, p. 43). In somewhat similar fashion the Indian tale in which a boy laughs till he is black in the face (p. 48) would seem to owe its existence to a white man's phraseology,[87] if not to the white man himself.

Savages the world over have believed that by eating the heart, liver, or other parts of the body they could acquire the courage, strength, or other qualities of an animal [88] or a human being. This is sufficient explanation for the blackness caused by eating liver and the redness from eating lungs and blood (see p. 41).

In the lore of many nations numerous virtues and powers have been ascribed to water, especially to running water. From Greek lore, for instance, we learn that the river Crathis, near Sybaris, was supposed to make yellow or white the hair of persons who bathed in it.[89] We ourselves sing with spirit, "Wash me and I shall be whiter than snow." It is not surprising, therefore, that untutored peoples endowed water with power to change the color of the skin (see p. 49).

The best of the Indian stories were constructed upon the basis of myths and racial experiences. The Indian assumed that he came from the earth [90] just as naturally as Greek and Italian tribes believed themselves autochthonous. Hence he thought that the three races with which he was familiar had originated from earth of different colors. His habit of painting his body would facilitate such reasoning.

Since the first men were made of clay they had to be moulded and

[86] In one idiom we become "white as a sheet."

[87] We also speak of turning green with envy, purple with anger, yellow with jealousy, black with fury, and blue with cold.

[88] For a good example in the classics see Porphyrius, *De Abstinentia*, 2.48.

[89] Strabo 6.1.13.

[90] According to one story, the Choctaw "came from the bosom of the earth, being made of yellow clay, and no men had ever lived before them." See Bushnell, as cited in note 40.

baked. As in the original experiments with vessels of this material, one was baked too little, another too much, and a third just enough.

We have seen that it is almost a constitutional matter for naïve races to postulate the color of their own bodies as the original color of all mankind or as the culminating color. They may go so far as to create gods in their own likeness. Xenophanes remarks that the ancient Ethiopians made their gods black and snub-nosed and that the Thracians represented theirs with blue eyes and red hair.[91] A similar attitude is manifested when an illiterate Negro of today preaches "dat de Great I-Am is a nigger" [92] and when Negroes in humble cabins purchase at exorbitant prices Bibles which have pictures showing black angels.[93] Highly educated nations also reason from the known to the unknown, but it is from ignorance and naïveté rather than from ethnocentrism that untutored tribes and races imagine that strangers of another color had ancestors like themselves.

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[91] Xenophanes also says that, if horses and oxen had hands and could paint, they would paint their gods like horses and oxen. See Burnet, J., *Early Greek Philosophy*, Third Edition (London: A. and C. Black, 1920), p. 119.

[92] Peterkin, Julia, *Black April* (New York: Grosset and Dunlap, 1913), p. 249.

[93] *The Americanization of Edward Bok* (New York: Charles Scribner's Sons, 1922), p. 141.

DATED INDIAN BURIALS IN MICHIGAN

GEORGE I. QUIMBY, JR.

THIS paper encompasses those facts which are pertinent to the significance of Indian burials of the historic period in Michigan and to their dating by means of trade objects associated with them. Unfortunately, little attention has been paid to this subject, which may provide links between history and prehistory, and the documentation accompanying museum collections is extremely meager. In addition to establishing such links, this study may offer social implications of an accultural nature.

I

In 1921 an extended skeleton of a young adult male (?) was excavated in a gravel pit one mile west of Tecumseh, in Lenawee County.[1] The lower quarter of the left ear has been preserved by the silver sulphide precipitated from two silver earbobs suspended from the pierced ear lobe. Associated with the skeleton were eight silver ornaments and a small ovoid glass mirror.[2] One of these silver ornaments is illustrated in Figure 9.

Artifacts of native manufacture are a medium-sized ovate, narrow, straight-base, chert projectile point with a straight to slightly contracting stem and a receding shoulder [3] (Fig. 8), found within the left chest of the skeleton, and small tubular shell beads among which, irregularly spaced, were the pierced metapodials, astraguli, and calcaneum of a cottontail rabbit (*Sylvilagus floridanus mearnsii*). Some of these bones are covered with red ocher (Fig. 11).

On the basis of datable trade-silver artifacts the earliest possible date for this particular burial is between 1784 and 1810. The silver

[1] Cat. Nos. 158–166, 5427–5428, Museum of Anthropology, University of Michigan. Other articles in this museum will be cited by catalogue numbers only.

[2] Other ornaments have been described and discussed in another paper by George I. Quimby, Jr., "Notes on Indian Trade Silver in Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 22 (1936) : 15–24. 1937.

[3] Coe, Joffre L., University of North Carolina, "Classification of Chipped Stone Projectile Points." (*In manuscript.*)

is probably all of British origin.[4] The projectile point, which may possibly have been the cause of death, was doubtless only secondarily associated with the skeleton. The only artifact of native manufacture which could be attributed to this particular Indian is a shell and bone necklace with the red ocher.

II

Near the center of Section 4, Clinton Township, Lenawee County, the burial of a young adult female was found in 1923 by the highway department in the course of road construction.[5] Unfortunately no information is available concerning the position of the skeleton. Accompanying the burial were a pewter teaspoon and two silver armbands in a fragmentary condition. The latter were stamped with the Roman letters 'AS' in a rectangular cartouche.

This touchmark is not identified, but thus far there have been found in Michigan no silver objects manufactured before 1780.[6] Furthermore, the earliest documentary evidence dealing with the manufacture of Indian silver ornaments is dated 1750.[7] It is quite unlikely that this Indian was buried before 1780.

III

At the Furton site in St. Clair County, about five miles south of New Baltimore, erosional forces recently exposed a burial in the sandy bank along Lake St. Clair.[8] Information concerning the skeletal material is lacking, but associated with the burial were the following objects: a brass tomahawk pipe, an iron strike-a-light, an iron knife blade, a white clay trade pipe with 'TD' stamped upon the stem side of the bowl (Fig. 1), a silver crown, sixteen miniature round silver brooches, and a medium-sized, double-barred silver cross made by Robert Cruickshanks of Montreal (Fig. 6). Also one potsherd, grit-tempered and with a cord-wrapped paddle impression, and a fragment of deer mandible (*Odocoileus virginianus borealis*) were found, but these probably were included in the fill of the grave and may be manifestations of an earlier occupation.

To judge from the identification of the mark upon the silver cross, the earliest possible date for this burial is between the years 1781 and 1809.

[4] Quimby, *op. cit.* [5] Cat. No. 898. [6] Quimby, *op. cit.*
[7] Gillingham, Harrold E., "Indian Silver Ornaments," *Penna. Mag. of History and Biography*, 58: 97–126. 1934. [8] Field Cat. Nos. F9–F20.

IV

In 1923 workmen excavating for a cellar on the Captain Smith farm on Harsen's Island in Lake St. Clair exposed several Indian burials in a gravelly knoll. No data on the position of skeletons in the graves are available. With one of these burials were associated the following objects:[9] two badly patinated basal parts of pewter vases, two small brass pots, two gunflints, a bell-shaped brass nozzle, threaded at the base and filled with wood, a double-barred silver cross, a brass bracelet (Fig. 10), and a Stiegal glass bottle with decorations painted in white, black, green, yellow, red, and blue enamel (Fig. 14).[10] With this burial were included an ovoid implement of reddish chert and a wooden spoon with a bird carved on the handle.

Heinrich Stiegal of Manheim, Pennsylvania, the first to produce in America glass so decorated, made his enameled glass between the years 1772 and 1785.[11] Therefore the earliest possible date for this burial falls sometime between these years. Supplementary evidence for this date is the presence of the silver cross.

The only artifacts of native manufacture associated with this burial are the wooden spoon carved on the handle and the chipped reddish chert implement. It is possible that the implement represents an older occupation and was accidentally included in the grave fill instead of having been intentionally placed there, like the other artifacts.

[9] Cat. Nos. 740–752.

[10] This bottle is 15.2 cm. in height, 13.1 cm. base to shoulder, 6 cm. face to face, and 7.4 cm. side to side. It is octagonal in cross section, owing to four bevel-like areas connecting the two sides and faces. Enclosed within an egg-shaped outline in yellow, on either face, is a white dove surmounting a yellow cross-shaped twig rising from olive-green foliage. On each outside edge of this border are white frills. At the top is a solid green circle from which radiate leaves of red and white, yellow, blue and white, and red. A similar design is at the bottom of the oval frame. On either side is a floral motif consisting of a vertical white stem with leaves of red and white, red, yellow, and blue and white arranged symmetrically on both sides of the stem. Surmounting the stem is a three-petaled olive-green flower. The same design, white frills and yellow leaves, appears on all four of the short interfacial side areas. Encircling the shoulder area is a band of blue relieved by white dots and curved lines. Occasional parts of all the design motifs are sharpened by black lines. The pontil mark is elliptical and surrounded by units of parallel curvilinear grooves, the whole having been somewhat smoothed over.

The bottle top is of lead or pewter and may have been gilded. It screws on a fitting of similar material fastened to the upper rim and lip of the bottle.

[11] Knittle, Rhea Mansfield, *Early American Glass*. New York, 1927.

V

In a sandy beach ridge along the shore of Lake Michigan between Cross Village and Goodheart in Emmet County Mr. L. P. Rowland between the years 1875 and 1900 excavated several Indian burials.[12] Unfortunately he kept only a general record of his findings and, consequently, a number of his burials must be treated as one unit. Further, because of lack of documentation only a proportionately small number of objects represented in his large collection may be definitely attributed to these burials. From one of these graves came the skeleton of a woman.

Associated with the various burials were sixty-three marked silver ornaments, at least fifty of which were made in Montreal, one in England, and two in the United States. These ornaments were manufactured between the years 1780 and 1810. Therefore, on the basis of the silver, these particular burials would have an earliest possible date between 1781 and 1810.

Since the area including Cross Village and Goodheart has been continuously occupied by the Algonquian-speaking Ottawa and Chippewa or Ojibwa tribes since 1741, it is quite probable that these burials may be attributed to them.[13] That they were allies of the British is certainly reaffirmed by the amount of British silver present.

Native artifacts associated with these burials are as follows: five square thin catlinite beads, a small skin bundle filled with vermilion paint (Fig. 7), a plain and rather crudely carved wooden spoon, a small ovoid wooden bowl (Fig. 2), and a fragment of a shell gorget with a countersunk perforation (Fig. 4).

Trade objects other than silver associated with the Cross Village - Goodheart burials are three copper or brass pots, two of which have iron bails, large quantities of colored glass beads, and several fragments of cloth. Identification of materials and weaves[14] showed three types: (1) a brown woolen broadcloth of plain plaiting somewhat felted; (2) a dark wool cloth of twilled weaving (two strands over and two under); and (3) blue material with a weft of linen and a woof of silk. The third type of weave is now called "grosgrain" and is used in making ribbons.

[12] Cat. Nos. 989, 1033, 1035, 1039, 1054, 1055, 1057, 1058, 1060, 1063, 1067, 1071, 1083, 1087, 1116, 1130, 1139.

[13] Greenman, E. F., "History of the Indians of Michigan." (*In manuscript.*)

[14] Identification by Volney H. Jones, Ethnobotanical Laboratory, University of Michigan.

VI

In 1900 a burial was excavated by graders at the site of the present post office in the village of Franklin, Southfield Township, Oakland County.[15] The skeleton was in a flexed position, and the following trade articles were associated with it: a bone-handled jackknife with a single blade, an iron tomahawk pipe, a silver armband with the stamped Roman letters 'CG' in a square cartouche, a silver armband with a snake engraved upon the face, manufactured by Robert Cruickshanks of Montreal, and two silver hair plates made by the firm of George Heming and William Chawner of London, England, 1781–82.[16]

Additional artifacts found with this burial were a shell gorget, a polished stone celt, and three medium-sized chert projectile points. The shell gorget is ovate; it is curvate in cross section. In the upper third of the gorget at each side are perforations which are countersunk.

The shapes of the projectile points vary. One is narrow and triangular, with a straight base and a contracting stem (or corner notch); the second, broadly ovate, with a convex base and a contracting stem (or corner notch); the third, narrow and triangular, with a straight base and a slightly contracting to straight stem.

Identification of the manufacturers of the accompanying trade silver places the earliest date for this burial between the years 1781 and 1809. The presence of the native artifacts is of particular interest.

VII

On the farm of Miner L. Cook, near Cook's Bridge in Cascade Township, Kent County, the skeleton of a young adult female (?) was excavated from a gravel pit some years ago.[17] Beside the skeleton were a small copper kettle, a badly patinated iron strike-a-light, small white glass beads, a pair of iron scissors, heavily encrusted,

[15] Artifacts associated with this burial are in the Detroit Historical Society Museum.

[16] The touchmark, 'GH' over 'WC' in a square cartouche, was tentatively identified by John Marshall Phillips, Gallery of Fine Arts, Yale University. This identification was tentatively suggested by Mr. Harrold E. Gillingham of Germantown, Pa. Sketches and a written description of this mark were sent by letter to these two men.

[17] Cat. Nos. 112665–112674 in the Grand Rapids Public Museum (formerly Kent Scientific Institute).

four wooden button molds, miniature round silver brooches, and a medium-sized double-barred silver cross, stamped with the Roman letters 'CG' in a square cartouche.

Artifacts of native manufacture are a long, flat, curved bone needle, and the bone handle of an iron awl. The bone needle is about nine inches long, a half inch wide, and an eighth of an inch thick. Near its middle is a drilled hole, countersunk from both sides. One edge of the proximal end has three closely spaced shallow crenulations. The bone handle bears a decoration of incised straight lines obliquely placed, right to left and left to right, joining at each extremity.

Because of the presence of trade silver ornaments it is reasonable to assume that the earliest date for this burial falls between 1780 and 1815.[18]

VIII

On the north side of Dowagiac Creek, about one mile east of its junction with the St. Joseph River (near Niles, Berrien County), a historic burial was exposed in a sand ridge during the excavation of a cellar in 1935.[19] Three skeletons came from this ridge. One of an adult female (?) lay in a flexed position. At its feet was a large brass kettle with an iron bail, and in its left hand was a polished stone pipe. Associated with this skeleton and to the east was that of a child with which were buried a number of miniature round silver brooches, two small brass "jingle bells" (Fig. 3), and a large iron spoon. Information about the position of the child's skeleton is lacking. About seven feet southwest of it was the extended skeleton of an adult female (?). Laboratory examination revealed fragments of trade cloth adhering to the bones.

The polished stone pipe with the female (?) skeleton is typologically related to the white clay trade pipes. The bowl extends obliquely from the stem, and at the bottom of the bowl is a spur (Fig. 5). It is interesting to note the retention of a native technique and its application to an introduced form.[20]

Although European forms of pipes to which the stone pipe is

[18] See note 6.

[19] Cat. Nos. 4590–4599.

[20] Mr. Peter Brannon, of Montgomery, Alabama, has noted similar examples from historic burials in the South (e.g. pottery kettles so faithfully executed after the European form that they have even the reinforcements with nonfunctional rivets where the bails are fastened).

related typologically may have been seen in this region at a much earlier time, the presence of the miniature round silver brooches suggests that the earliest possible date for this burial is between 1780 and 1815.

IX

During landscaping operations in the State Park, West Allis Township, in Presque Isle County north of Onaway (southeast shore of Black Lake), a number of historic burials were excavated in 1934.[21] Because of insufficient data these burials must be taken as one unit. Skeletal material includes bones of males and females, young and middle-aged adult. Associated with these burials were nine silver ornaments, fragments of copper kettles, a badly encrusted jackknife, three heavily patinated iron knives with wooden handles, one gunflint, two fragments of strike-a-lights, colored glass beads of various shapes, sizes, and colors, one white clay trade pipe with bowl extending obliquely from stem and spur at bottom, fragments of plain-plaited (somewhat felted) brown woolen broadcloth and green-blue plaited silk, and a small rectangular mirror. There were no artifacts of native manufacture associated with these burials.

Again, on the basis of the trade silver ornaments, the earliest possible date for this burial is probably between 1780 and 1815.

X

In 1922 a very poorly documented burial or burials collected from an unknown site in Leelanau County revealed the following trade artifacts:[22] two iron knife blades, badly encrusted, three fragments of white clay pipe stems of European form, one of which has a green glaze, one iron needle, a fragment of a medium-sized brass sleigh bell, one fragment of green pressed glass (Fig. 16), one fragment of blue and gold lusterware china (Fig. 13), the basal part of a glass bottle which has a rough pontil mark (Fig. 15), a large fragment of a mulberry-colored Staffordshire teapot (?) (Fig. 12), and a number of blue glass beads.

Artifacts of native manufacture are one deer antler projectile point, a fragment of charred bone with an incised crosshatched design upon it, a large piece of worked antler, and a fragment of a stone

[21] Cat. Nos. 4601–4603, 4722–4724, 4734–4736, 5411–5426.
[22] Cat. Nos. 124–127, 1369.

pipe bowl. Possibly these artifacts are camp or village refuse from a previous occupation which was accidentally included in the grave fill. Since there are no data concerning skeletons or positions of skeletons, or relationship of artifacts to the burials, very little trustworthy information can be secured in this case.

Using for a chronological aid the mulberry-colored fragment of Staffordshire-like china which has an oriental motif for decoration, one finds that the earliest possible date for this burial would be *c.* 1830, for it was not until then that the English potters had access to the lithographing process which enabled them to print cheaply colors other than blue.[23]

XI

In 1935 excavations by a farmer on his land west of Port Austin in Huron County revealed several burials of the late historic period.[24] Accurate information concerning the skeleton is lacking, but associated with this burial were the following trade artifacts: eleven gunflints, the fragments of a flintlock gun, including lock, barrel, and German silver fittings, two lead balls (shot), a number of small glass beads, and fragments of brown, plain-plaited, woolen broadcloth, somewhat felted.

None of the trade artifacts give any clue to the date of this burial, but in a letter to the Museum a very old lady who was an early settler in the region claims that this was the burial of the "Cheaf," and that he died in 1862. She claims, further, that her mother, the local missionary at that time, preached the funeral sermon, and the "Cheaf's" first gun, a flintlock, was buried with him.[25]

The skulls from these Indian burials of the historic period, taken as a group, are round. The range of the cephalic indices is from 78.15 to 88.64, and the mean cephalic index for the group is 82.19. The skulls as a group are hypsicranial (high-vaulted), and the eye orbits are of medium proportions (mesoconch). The nasal proportions are variable, some mesorrhine, one chamaerrhine, and some hypochamaerrhine. All the skulls are undeformed.[26]

[23] Camehl, Ada Walker, *The Blue China Book.* New York, 1916.

[24] Cat. Nos. 4726–4733.

[25] Her claim is not beyond the realm of possibility, and I include it for what it may be worth.

[26] On the basis of limited cranial measurements and observations made by Mr. Georg Neumann upon skulls Nos. 159, 591, 754, 898, 1268, and 4722–4724.

SUMMARY AND CONCLUSIONS

The dates of manufacture of the various kinds of trade objects found in Indian burials of the historic period in Michigan give a reasonably accurate clue to the earliest possible dates for these burials. Use of this method reveals that such dates for most of the burials studied are between the years *c.* 1780 and 1815, although it is possible that any one of the burials occurred at a much later time. Some burials seem to have been made at least after 1830.

Identification of the place of manufacture indicates that most of the trade objects were of British origin, and probably belonged to Indians who were friendly toward the British. This is apparent from the silver ornaments alone, since both Americans and British used silver for gifts and for trade. There is the possibility that the silver may have been captured from the British by Indians friendly to the American colonists, but if this is so, one would expect to find in the burials a reasonable proportion of silver ornaments manufactured in the United States. Therefore it seems that most of the burials reported upon in this paper belong to Indians who were well disposed toward the British throughout the period from 1780 to 1815. The tribes in Michigan which fit into this category are the Ottawa, the Chippewa, and the Potawatomi.[27] Documentary evidence indicates that the Ottawa and the Chippewa occupied the Emmet County site previously mentioned.

Some of the burials of this period contained artifacts showing prehistoric technique and form, and one burial had an artifact which illustrates prehistoric technique applied to a historic European form. All the burials had trade objects, although the cultural pattern of the burial itself was prehistoric. This culture pattern was so widespread and its manifestation so general during prehistoric times that there is little chance of identifying the tribe by means of the position of the skeleton and the relationships of artifacts within the historic burials.[28]

Mr. Neumann pointed out that skulls associated with trade materials in the upper levels of the Fisher Site, Will County, Illinois, also conformed to this type, and had tentatively been identified as Potawatomi by means of the direct historical method. All the trade silver from this site that I have examined at the Department of Anthropology, University of Chicago, was made between 1780 and 1810.

[27] *Encyclopaedia Britannica*, Eleventh Edition, XII: 553a.

[28] Griffin, James B., "Aboriginal Mortuary Customs in the Western Half of the Northeastern Woodlands Area." (*In manuscript.*)

Ethnological studies of primitive peoples in the process of culture change and archaeological investigations of historic sites in other regions have shown that, with the type of contact which occurred between Indians and white groups, the aboriginal technological culture changed before the social culture. The facts presented in this study, namely, that grave furniture of white manufacture was substituted for native grave furniture, although the cultural concept of placing objects within the grave remained the same, agree with or conform to the results of studies made in other areas. Further, there is the possibility that old techniques were employed in producing new forms (in the technological culture) when these forms, once having been observed, were not available to an individual.

Considerable work in this subject remains to be done in the laboratory as well as in the field. In addition, there exists the strong probability that links between history and prehistory will be discovered through such a study. There is also the possibility of revealing facts of interest in the study of continuous first-hand contact between groups possessing different cultures.

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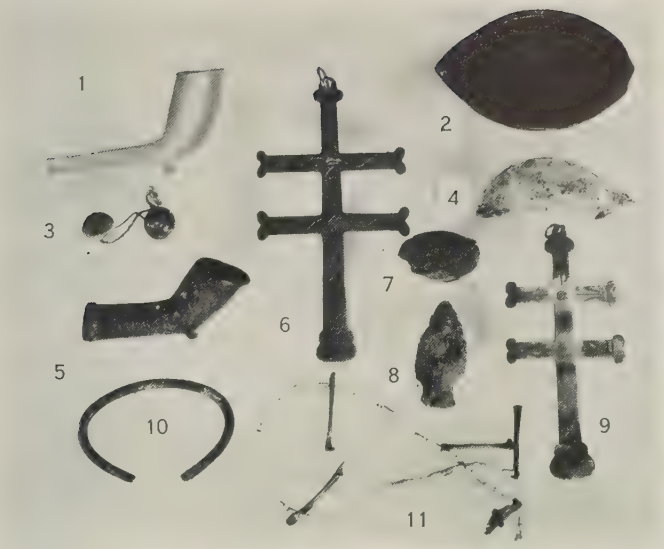

ARTIFACTS WITH HISTORIC INDIAN BURIALS

1. Clay trade pipe from Furton site
2. Carved wooden bowl from Cross Village, Goodhart burials
3. Brass jingle bells from burial near Niles
4. Fragment of perforated shell gorget from Cross Village, Goodhart burials
5. Stone imitation of white man's clay pipe, from burial near Niles
6. Double-barred silver cross found with burial at Furton site. Manufactured by Cruickshanks
7. Skin-covered packet of vermilion from Cross Village, Goodhart burials
8. Chert projectile point from burial near Tecumseh
9. Double-barred silver cross from burial near Tecumseh. Manufactured by Arnoldi
10. Brass bracelet found with burial on Harsen's Island
11. Necklace of shell beads and rabbit metapodials from burial near Tecumseh

ARTIFACTS WITH HISTORIC INDIAN BURIALS

12. Fragment of china of Staffordshire type from burial in Leelanau County
13. Fragment of lusterware china from burial in Leelanau County
14. Stiegel glass bottle from burial on Harsen's Island
15. Basal fragment of glass bottle found with burial in Leelanau County
16. Fragment of pressed glass found with burial in Leelanau County

CULTURE TYPES AND CULTURE AREAS IN SOUTH AMERICA

DAVID B. STOUT

THE purpose of this paper is to give a brief sketch of each type of culture indigenous to South America and to consider the area in which it occurs. The emphasis throughout has been placed on classification, for there has been no attempt to determine centers of distribution from which cultural traits and trait-complexes have diffused. Rather, we should regard this as a classification of basic culture types, each of which may be subdivided by considering the distribution of more traits and trait-complexes. The number of types of culture, nine, was arrived at after a survey of the literature had been made and the occurrence of traits had been noted. To this information were added the results of previous distributional studies by other workers in this field. Limitations of space do not permit a complete characterization of each type; hence only the most salient features are pointed out. The accompanying map (Fig. 1) gives the location of several typical tribes and the approximate boundaries of each culture type. The boundaries are not to be interpreted as marking sharp breaks in type of culture, but, rather, as marking zones of transition. Early extinction of many tribes and poor information also add difficulty in determining the extent of several of the culture types.

I. ONAN

The Onan type of culture takes its name from the principal tribe, the Ona, inhabiting the northern and eastern portions of the island of Tierra del Fuego. The only other tribe of this culture type is the Haush, now extinct, which was closely related linguistically, somatologically, and culturally. These two tribes have been called "Foot Indians," and properly so, for they possess neither horses nor canoes. The economy of this culture is based on hunting, gathering, and fishing. Their principal weapon is the bow and arrow, which they fashion with great skill and care. In fabricating an

arrow six of the fourteen materials and seven of the nine tools known to the Ona are used. It is employed almost exclusively in wars, feuds, and duels. Other weapons are crude spears and, occasionally, slings.

FIG. 1. South America, showing the location of the nine types of culture

The chief food is guanaco meat, though foxes, seals, eels, fowl, shellfish, roots, and berries are hunted, trapped, or gathered. Clothing is made of untanned guanaco skins, several of which are sewed together and worn mantle-fashion with the fur side out. Moccasins

are fashioned of guanaco skin and stuffed with grass. Shelter is afforded by a crude windbreak of skins stretched between trees or lashed to poles. Fire is generated with flint and pyrites.

As a consequence of their hunting and gathering activities the social organization is loose; it is composed of a number of bands, each of which exploits its own territory running from the mountains to the sea. These bands are exogamous and are led by a chief whose powers are not very well defined. Monogamy prevails, though polygyny is permitted for those who can afford it. Descent is patrilineal.

There is a distinct pattern of modesty, for even a successful hunter does not boast of his kill. Neither is it proper to show excitement at wrestling matches or to grieve in the event of death. All young men pass through an initiation period that lasts several years. The initiators wear painted bark masks that represent various natural spirits. Religious beliefs center about a great number of good and bad spirits, which inhabit all natural objects. Shamans, usually male, control these spirits, prophesy, and cure illnesses. Burial is simple inhumation.

Onan culture may be regarded as a survival of the original culture which once probably spread over the whole of southern South America east of the Andes. The languages spoken by the tribes of this type are related to the Tehuelche language north of the Straits of Magellan.

II. PAMPEAN–PATAGONIAN

The area extending from the Andes to the Atlantic Ocean and from the Straits of Magellan to approximately the 30th parallel of latitude was inhabited by a number of tribes, all of whom possessed a considerable degree of cultural similarity. Many of them were early exterminated, though remnants of some still exist in the southern part of the area. Languages of four linguistic stocks are or were spoken by the peoples of this culture type: Charruan, Puelchean, Araucanian, and Tehuelchean.

The nomadic mode of life led by these tribes was intensified with the advent of the horse in the early sixteenth century. They live in movable shelters made of hides and short poles. Most of their hunting is done on horseback. Guanaco drives are organized and led by the band chief. The principal weapon is the bolas, which is used to bring down the hunted animals. They are then dispatched

with a spear. Bows and arrows are also used, but the arrows are carried in the headband rather than in a quiver. Ostriches, berries, seeds, and fruits are among the other foods. Guanaco-skin capes, painted on the hairless side, and boots made of horses' hocks are worn. Woven headbands are the limit of textile manufacture. Though these tribes once made pottery they do not now, owing to their many movements on horseback, which render pottery impracticable. The fire drill is used.

In time of war a number of bands fight under the leadership of a head chief, but these alliances dissolve as soon as the need for them has passed. There is little elaboration of the social system, the general pattern of which is the same as that of the Onan culture. Shamans practice medicinal bloodletting and have a rattle as part of their equipment. Burials are not the simple inhumation of the Onan type of culture, but are covered with stone cairns.

The tribes in the northern part of the Pampean–Patagonian area have been influenced by the more complex cultures of the Chacoan peoples. Thus there are here a few minor traits, such as the substitution of mats for skins in the covering of shelters, greater use of tattooing, lip, ear, and nose plugs, finger mutilation as a sign of mourning, basketry, and a greater practice of weaving and pottery making. The occurrence of these traits in the northern part of this culture type does not, however, change the essential nature of the culture of these tribes.

On some of the islands of the Paraná delta there once dwelt a tribe which practiced agriculture, lived in permanent houses grouped in villages, and was cannibalistic, and thus represents the southernmost extension of aboriginal agriculture east of the Andes. This tribe is not a part of the Pampean–Patagonian culture type, but rather belongs with the Amazon–Orinocoan type, which will be discussed later. Some of the inhabitants of the Pampean–Patagonian area were of relatively recent arrival, for they crossed over to the eastern side of the Andes from the west and adopted the nomadic, horse-riding culture of this culture type.

III. MAGELLANIC

West and south of the Andes, from Chiloe Island to the Fuegian Archipelago, there live three tribes whose culture is markedly different from that east of the Andes. These are the Chono in the

north, the Alacaluf farther south, and the Yahgan in the extreme south. All dwell on the numerous small islands or on the coast of the mainland. Each tribe belongs to a separate linguistic stock.

Here also the social organization is relatively simple, being based on limited families which are grouped into small bands led by a chief with little real power. Marriage, which is exogamous for the bands and endogamous for the tribes, is usually monogamous though sometimes polygynous. Descent is patrilineal. The Magellanic type of culture differs mostly in respect to its economy and technology. Almost all food comes from the sea; it includes fish, seals, limpets, shellfish, and sea otters. To secure their food they employ five kinds of spears and harpoons, nets, and bark canoes. The canoes are equipped with a fireplace. The bow and arrow is little used among these tribes since dependence is placed on the harpoon and the spear. Slings and clubs are also a part of their material possessions. Baskets of several types are made, some of which have a very intricate weave; other containers are fashioned of bark or skins. Several practices also serve to distinguish these tribes from those of the two foregoing areas. These are: abortion and infanticide, which are frequent; premarital laxity, which is common; and bathing of mother and child soon after childbirth.

There are a few Araucanian influences in Chonos culture, but they are not strongly developed and do not affect the essential homogeneity of Magellanic culture. These are as follows: some maize and potato growing, maize chicha, the plank boat, fiber and bark clothing, and rudimentary slavery.

IV. ARAUCANIAN

On the western slopes of the Andes from Chiloe Island northward to the Rio Maule there occurs a type of culture quite distinct from those surrounding it. This area is inhabited by several tribes who speak languages belonging to the Araucanian stock. The low passes in the mountains permitted several tribes to cross the Andes, in historic times, to the Pampean–Patagonian area and to adopt that mode of life. These tribes were mentioned in connection with the latter culture type and bear little relation other than linguistic to the tribes and culture of the Araucanian area.

The tribes of this culture type are remotely related to those of the three previous ones. Though the same general pattern of social

organization prevails here also, there are additions. Each village is ruled by a chief whose office is hereditary and who is advised by a council of elders. There are also a tribal chief and a war chief. Agriculture is practiced here, and maize, beans, and quinoa are grown. The introduction of horses and cattle served only to intensify the practice of animal husbandry, for the Inca had previously introduced llama breeding. Fishing is extensively practiced on the coast, whereas agriculture is an important factor in the life of the inland groups. Piñon nuts were once gathered in large quantities each season and were a staple food for many of the Araucanian people. Chicha and maize beer are used in great quantities.

Cooking is done in earthenware pots, which are made by coiling and modeling with the hands and a spoon-shaped stick. Finer pottery is glazed, or incised and inlaid with white clay and refired. Wooden bowls and spoons are used in eating. Habitations are rectangular wattle and daub huts with thatched roof, or, in the southern part of the area, plank houses. Water transport is by balsas, dugouts, and plank canoes.

Most clothing is of woven bark fiber or wool. It consists of a breech cloth and a poncho for the men and a mantle for the women. The Araucanians learned metal working from the Incas, and they still practice it expertly in the fashioning of silver ornaments. Face and body painting occur to a considerable degree.

There is present here a well-developed pattern of organized warfare, which has its beginnings far in the past. These tribes repelled the Conquistadors and, later on, successfully opposed the Chilean government, until they were finally subjugated in 1882. Even the Incas were unable to make many successful inroads into Araucanian territory. Weapons consist of bows, spears, slings, and elbow clubs. Arrows were at one time poisoned. Hide helmets, coats, and shields serve as armor. Captives of war were formerly tortured and killed. Ceremonial cannibalism and slavery were also once practiced.

Dealings with the supernatural are carried on by diviners, sorcerers, and exorcists, of whom the last group is the most important. They cure by bloodletting, manipulation, and chanting. Their equipment includes drums, rattles, and flutes. At one time sitting burial and urn burial were both practiced, though coffins are now used. The Araucanians believe in a group of malignant deities, who are greatly feared and who are propitiated in times of stress.

V. PERUVIAN

The Peruvian area, the best known of all in South America, was populated by a number of different tribes who spoke languages belonging to several different stocks. There was, however, a political hegemony established by the Quechua-speaking Inca tribe during the four centuries preceding the Conquest. It is the culture of this period that we shall consider typical.

Peruvian economy was based on highly developed agriculture in which terraced irrigation, fertilization, and spades were employed. The principal crops were maize, quinoa, potatoes, and beans; and in the moister valleys manioc, tobacco, cotton, various fruits, and coca were raised. The llama and the alpaca were bred for their meat and wool and were also used as beasts of burden. Guinea pigs, dogs, and ducks were also bred. Hunting was regulated so that the natural supply of animals would not be exhausted. The weapons were spears, atlatls, clubs, slings, bolas, and blowguns. Fishing was done with nets, poisons, harpoons, and lines.

The lower classes dwelt in small one-story, rectangular huts made of adobe, stone, or wattle and daub. Officials had more capacious and elaborate homes, though these, like the huts of the lower classes, had thatched roofs. The men wore a loin cloth and a poncho; the women, a blanket fastened at the shoulder with a pin. Both sexes wore capes and sandals or shoes. Personal decoration included tattooing, body and face painting, and metal ornaments of great variety.

Stone, wood, and metal working were highly developed, as were weaving and pottery making. Aqueducts brought water for irrigation. Travel was facilitated by excellent roads, suspension bridges, and balsas. Each family was allotted a strip of land sufficient to support it. In addition, the men worked communal lands for the religious and state officials, served in the army, or aided in the construction of public works.

The social and economic unit was the family, which, in the lower classes, was formed by a monogamous marriage. One hundred families constituted a "clan." These "clans" were grouped into phratries or "tribes," which in turn formed provinces and quarters, all of which had officials at their head. The whole system culminated in the Sapa Inca, "Son of the Sun." There were also a number of social classes, each with its own duties and privileges. All males

were placed in one or another of ten age grades, each with its particular statuses and rôles. Inheritance was patrilineal in some parts of the empire, matrilineal in others. Censuses were taken at regular intervals, the records of which were kept on quipus.

The religion was a combination of animistic, totemistic, and fetishistic beliefs, upon which the ruling Inca class superimposed the state religion, which revolved about the worship of the sun, thunder, and the moon. Sacrifices of all sorts were made to these deities, and temples were built and maintained throughout the empire by an organized priesthood. The dead were flexed, wrapped in leaves and cloth, and placed in pits in the ground or in caves. The mummification that followed was natural, owing to the dry climate, though there is some evidence that artificial mummification was practiced. Food, implements, and personal possessions were placed with the dead.

The Peruvian culture type includes also the Diaguite (or Calchaqui) civilization of northwest Argentina and the Atacama civilization of northern Chile. In these the basic pattern of life was the same as in the Peruvian highlands, though the high degree of complexity of social organization was not present. The Diaguite civilization contains a greater variety of copper and bronze objects than that in any other part of the Peruvian culture type. The Atacama civilization made a greater use of bone in its manufactures. The bow and arrow, relatively uncommon in Peru, is frequently found here.

Ecuador also was the seat of several civilizations, all with much the same economic base as the three just mentioned. Most of the Ecuadorian tribes of more complex culture were included in the Caras confederacy, which was annexed to the Inca empire shortly before the Conquest. Stonework, pottery making, weaving, and social organization were not so highly developed here, though nearly all the basic features of the Peruvian culture are present.

VI. CHIBCHAN

The Chibchan culture was located in western Colombia and was largely confined to the high mountain valleys and plateaus. The languages spoken there nearly all belong to the Chibchan stock. The center of the Chibchan dominion was Bogotá, in the upper Magdalena River valley.

As in Peru, the basis of economic life was agriculture and animal

breeding. Llamas and alpacas, however, were not found here. Emeralds and gold were mined by certain tribes and traded throughout the Chibchan area. Gold working was very highly developed, but bronze was not known owing to the lack of tin. Copper tools were scarce, but copper was alloyed with gold in fixed proportions. All cutting tools were made of stone, which was not much employed for other purposes.

There were no stone buildings; all houses and temples were built of cane and thatch or of wattle and daub. Cotton weaving was highly developed, and pottery was decorated in two or more colors by the negative-painting process, or was carved. Vessels with annular bases, commonly found here, indicate Middle American connections. Clothing for both sexes consisted of a loincloth and a shoulder mantle. All who could afford it wore gold ornaments of great variety, which were made in clay molds by the lost-wax process. Weapons were spears, atlatls, slings, and two-edged swords. Bows were not common.

Matrilineal descent and monogamous marriage, except for the higher ranking men who were permitted to have several wives, were general. The Chibchan territory was divided into five provinces, each of which was governed by a chieftain. Bogotá was the seat of one such ruler, the Zipa, head of the Chibcha tribe proper. The bravest warriors formed a privileged class, distinguished from other classes by their ornaments.

The bodies of dead chiefs were treated with a resinous substance and, after a period varying with the importance of the deceased, were secretly buried by the priests. Besides offerings of food and chicha at the grave wives and servants were sometimes buried alive. Among the Chibchas there were many medicine men and diviners; the latter made considerable use of datura in their divinations. Children were sacrificed to the sun, center of the religious cult, that it might live. For this purpose they were even reared in "schools" from early childhood. Bochicá, the culture hero, was a bearded man who came from the east. He was the special patron of the warriors, and to him gold only was offered as a sacrifice. The rainbow was the deity of childbirth. The Chibchan god of dancing, drunkenness, and singing was also the protector of weavers. These deities have exact counterparts in Middle America, which indicates a connection of some sort, though we are unable to say in which direction the

diffusion has occurred. Thatched huts served as temples. They contained idols made of gold, wood, pottery, etc., arranged in pairs — male and female. To these idols offerings of food, gold, and emeralds were made. There was an organized but ungraded priesthood, which was recruited from the sons of the priest's sisters.

The Chibchan culture type had a base like all the other civilizations of the Andes, but there are many minor differences, which, with the numerous evidences of Middle American connection, set it apart from the Peruvian type.

VII. AMAZON–ORINOCOAN

The Amazon-Orinocoan type of culture takes its name from the two great river systems in western Brazil, though it has extensions on the west coast, the east coast, and occurs as islands in the East Brazilian culture type. There are a great number of tribes and linguistic stocks in this area, though most tribes speak languages belonging to one of the five large stocks — Tupi, Arawak, Carib, Tukano, and Pano. The remaining languages, most of which form independent stocks in themselves, are spoken by tribes concentrated along the eastern front of the Andes.

Slash and burn agriculture occurs throughout the area; the plants grown include manioc, sweet potatoes, maize, and tobacco. Some cotton, cocoa, pineapples, certain species of canes, and several kinds of fruit trees are also raised in various sections. Maize, which is more commonly grown in the western part of the area, becomes quite rare in the east. There is no animal breeding whatever, except that which has been introduced by the whites. Fishing is more important than hunting; for it bows, spears, nets, traps, and poisons are used. Very few of the tribes employ hooks and lines. The principal hunting weapons are the bow and the blowgun. With the latter are used darts poisoned with curare. The blowgun occurs mostly in the west, as does the atlatl.

Because of the comparatively settled life of these peoples houses are relatively permanent. They are round or oval and are thatched; they have a post-supported conical roof or are rectangular with a gabled roof. In many places the whole community lives in one large house. Pile dwellings occur along the north coast. A characteristic trait of this type of culture is the hammock. Nearly all travel is by water, in bark or dugout canoes. Clothing is very scanty;

the men often wear only a penis cover. There is no footgear in most of the area. Some of the tribes along the eastern face of the Andes wear ponchos and blankets. Ornaments are arm and leg ligatures, and ear, lip, and nose plugs. Body painting and tattooing occur frequently, but are not universal.

Tools are made of wood, bone, teeth, and shells, for there is little or no stoneworking. Pottery is made by nearly all the tribes, though some engage in its manufacture more than others. Basketry in many varieties and weaving are practiced, but in many of the tribes the products are more for ornamentation than for utilitarian purposes. Bark cloth is made in several places.

The most important economic unit is the village community, which is headed by a chief. Marriage is monogamous, with some polygyny for chiefs or other more wealthy men. The couvade occurs sporadically here, and puberty rites frequently include severe endurance tests. Warfare is not particularly developed. In it are used bows, spears, clubs, and wooden daggers. Skulls of enemies are kept by some tribes, and cannibalism is practiced in several parts of the area.

The religion consists of animism and magic. The spirits are mostly evil, but can be appeased by the medicine men. In this type of culture masked dances in imitation of animals are commonly found. Drums, flutes, rattles, Panpipes, and trumpets are widely distributed, though there are some tribes who do not possess all these instruments. The dead are greatly feared, even to the extent that villages are sometimes immediately abandoned after a corpse has been buried. Urn burial is the most common form, but grave burial also occurs.

Though this type of culture is not continuous in its distribution, the traits and the trait-complexes just reviewed are found quite uniformly throughout. The islands and the extension of Amazon–Orinocoan culture in the east suggest that these are recent advances into the territory of the simpler, nonagricultural, peoples.

VIII. EAST BRAZILIAN

The East Brazilian culture type is almost always associated with the Gês linguistic family. It occurs in the highlands of eastern Brazil and as islands in the Amazon and Orinoco river basins. It is a much simpler type of culture than the Amazon–Orinocoan.

Tribes of this type of culture do not practice agriculture, but gain their entire food supply by hunting, fishing, and gathering. This necessitates considerable wandering; consequently their dwellings are but temporary shelters, made of bent branches covered with leaves. They do not have the hammock. Their clothing is very sparse, even nudity being reported for the area. In most of the tribes the men wear a tiara of feathers gummed to the head; the women, a number of necklaces and bracelets. Body painting is practiced, but more crudely than among the surrounding agricultural peoples.

They hunt with large bows and arrows, which are also used in fishing. Most of the tribes do not have canoes nor do they work stone, weave, or make pottery to any great degree. A little basketry is practiced, but most containers are bamboo internodes. Cannibalism was once very common among several of these tribes.

The basic social and economic unit is the band, composed of congenial or related families. It is led by a chief whose power is not great except in time of war. Marriage is monogamous, with some polygyny for the chiefs, whose prestige mounts with the number of wives they are able to support. These tribes are quite warlike, though they do not engage in warfare so much for material advantage as for revenge. They are the perpetual enemies of the agricultural peoples who are their neighbors. Duelling is resorted to in settlement of personal differences.

The religion of these tribes is animistic, and the spirits that people the world are almost without exception malevolent. Burials are made in a shallow pit in the deceased's hut or under a small shelter. Frequently the earth is stamped down so that the spirit shall not escape. At least one tribe practices secondary burial. Five men, who are regarded as temporary incarnations of the spirits, remove the body from the small mound in which it was first buried. They then clean the bones and place them in the village cemetery. Shamanism is not important or highly developed.

The relative simplicity of the East Brazilian culture is the feature that distinguishes it most from the types surrounding it. The isolated areas of this culture type in the Amazon-Orinocoan area suggest that they are remnants of the older, simpler, culture which was once more widespread and which has been interpenetrated and surrounded by the relatively recent agricultural peoples dealt with in the last section.

IX. CHACOAN

The area extending from the Andes to the Paraguay River and from approximately the 17th to the 30th parallel of latitude is inhabited by a number of tribes, most of whom speak languages belonging to one of the four following stocks: Guaycuru, Mascoi, Mataco, and Samuco. There are a few outliers of the Tupi and Arawak stocks, but these tribes are not so fully typical of the Chacoan type of culture as are those that comprise the four major stocks.

The economy of most Chacoan tribes is based on hunting, gathering, and fishing. In addition, some of the tribes practice agriculture to a moderate degree. Those that till the soil use the wooden spade, which has probably diffused from the Peruvian area. The nomadic horseless tribes live in dome-shaped huts made of bent saplings and thatched with palm leaves. The nomadic tribes who have horses live in portable dwellings constructed of poles and mats.

These tribes make pottery and weave quite fine cloth. Fishing tackle consists of hook and line and nets. Few of the Chacoan peoples have canoes or dugouts, but, rather, use pelotas to cross rivers. The bow and arrow is employed almost exclusively in hunting. Feather fire fans and knuckle-dusters, which occur here also, have evidently been diffused from Peru.

Each village is governed by a chief who, in turn, is generally subordinate to a tribal chief. These offices are usually hereditary and carry with them considerable power and influence. Monogamy is the commonest form of marriage, though polygyny occurs among chiefs and others who are economically able to support several wives. Clothing consists of a breechcloth and a mantle which is wrapped around the waist and extends to the ankles. Among the ornaments are woven headbands, in which feathers are inserted, netted caps studded with shells, bracelets, armlets, rings, and ear and lip plugs. Both sexes are tattooed and painted. Musical instruments include skin drums, gourd rattles, trumpets, flutes, and whistles. One kind of whistle, peculiar to this area, is disk-shaped. Games of chance and bat and ball games, which occur among most of the tribes of the Chacoan area, have evidently come from Peru. They rarely are found elsewhere on the continent.

The Chacoan type of culture appears as a blend of many traits from the surrounding areas. This blend is quite homogeneous and

involves a sufficient number of traits to permit us to consider it a separate culture type. For this reason the Chacoan culture was left to the last, for its ethnographic position is best understood after the principal features of the surrounding culture types have been discussed.

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THE HOPI METHOD OF BAKING SWEET CORN *

MISCHA TITIEV

ONE of the most interesting economic activities of the Hopi is the baking of sweet corn (*dupeve*) in old-fashioned earth ovens. As usual, the economic factor is not the only one involved, for a good deal of ritual is interwoven through the entire procedure. Baking takes place in mid-September, when sweet corn matures in northern Arizona, and is performed outside the village close by the field where the crop was raised. The farmer and his wife make preparations to spend two or three days away from home, and several relatives or congenial friends are invited to accompany them. A sheep is generally slaughtered to provide food, and bedding and other necessities are loaded into the wagon which conveys the party to the fields. A happy picnic atmosphere prevails from the very outset in spite of the fact that a good deal of hard work is to be done. Thus a man plans to leave the village early in the afternoon so that he may reach his destination before sunset; and immediately on his arrival he must unhitch, water and hobble his mules or horses, and then clean out the baking pit before he is ready to sit down to supper.

Early the next morning husband, wife, and most of the other members of the party begin to harvest the sweet-corn crop, while one of the women looks after the camp and one of the men starts a roaring fire in the baking oven. Among the Hopi these ovens are built in three parts (see Fig. 1). The main section (*gösi*), in which the actual baking is done, is a cylindrical pit about three feet in diameter and some eight feet deep. About eighteen inches away there is a second excavation, shaped like a bathtub and about three feet wide, about five feet long, and six feet deep. This part is called the nose of the oven (*yokaha*) and is used only for ventilation. Between the two

* This article is based on material gathered at Oraibi, Arizona, in 1933. The study was made during the course of a field trip financed and sponsored by the Division of Anthropology of Harvard University, to which grateful acknowledgment is made.

large pits there is a connecting tunnel about eighteen inches long, at a depth of approximately four feet, sloping upward to improve the draft.

Throughout the day the man in charge of the oven keeps a blazing fire going in the main pit, and from time to time the harvesters bring loads of corn, which are heaped just east of the oven. When the entire crop has been gathered and piled up beside the firepit the owner examines the walls of the *gösi*. If they have turned grayish white he decides that it is time to begin baking, but before starting operations he must perform a bit of prescribed ritual.

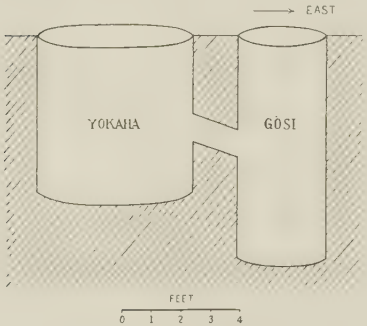

FIG. 1. An earth oven for baking sweet corn. The actual baking is done in the *gösi;* the *yokaha* is used only to create a strong draft

While the rest of the party stands about and chatters, the farmer takes some homespun cotton yarn and cuts a string that measures exactly three times the width of his hand. Two thirds of the string he doubles and twists together to form the so-called legs (*hokya'ata*) of his prayer offering; the remaining third is left to form what is called the breath (*hik'si*). At the juncture of the doubled and single parts he ties together an eagle feather and a feather from a little yellow bird (*sikya'tci*), which is said to be present throughout the corn growing season, from June to September. The eagle plume is supposed to carry the owner's prayers speedily to the sky gods; the yellow feather, to make the corn assume the proper color when it is baked. (There is a standing joke, corresponding to our jests about a young bride's biscuits, that a man's wife will leave him if his sweet corn does not bake properly.)

As soon as the feathers are tied in place the owner's wife hands him one of the largest and best ears in the crop. This ear is called "mother" and is now to be converted into a prayer stick (*paho*). As

the first step in this process the farmer carefully pulls the green husks part way down from the top, places the tied feathers against the kernels, and runs the breath line up to the tip of the ear. The pulled-down husks are then replaced so that they enclose the prayer offering, and to the outside of the mother ear there are now bound sprigs of a yellow plant called *ma'ovi* and of a gray bush known as *ku'ungya*.[1] These plants are tied in place with a string of yucca, and are included as prayers for good crops, plenty of grass, and other beneficial vegetation. The entire packet is known as a baked-corn prayer stick (*dupep paho*).

Four such packets are made in exactly the same fashion. While the last is being completed the farmer's wife picks an overripe ear which has begun to sprout tassels (*taka'la*) and, nibbling some of the kernels, mixes them with water in her mouth. She then spurts the mixture over the entire heap of corn, which is soon to go into the oven. This rite must be performed by the owner's wife, or by some other female relative or friend, and is considered to be absolutely essential to make the corn sweet, but it is very likely that a fertility motive is also involved.

As soon as the four mother ears have been properly converted into prayer offerings, the owner takes a handful of white cornmeal and makes four "paths" by sprinkling meal from each of the four cardinal directions toward the mouth of the circular pit. One of the ritual corns is placed on each path, and four people stand over them ready to push them into the oven when the signal is given. The owner's wife is usually assigned to the ear on the north path and begins the proceedings by sliding her mother ear into the oven. Then, in the customary ritual order, the other three people slide their corns in from the west, south, and east.

Immediately after the ceremonial circuit has been completed there is a mad rush by the men in the party to toss the entire heap of corn into the baking pit in any order, and as the ears go tumbling down the women hastily chew and spurt more of a mixture of kernels, sprouted corn tassels, and water over everything. Then the connecting tunnel is stopped up, and a lid consisting of several large slabs

[1] These plants have been identified by Mr. Volney H. Jones, of the Ethnobotanical Laboratory, University of Michigan. The yellow plant is a species of snakeweed, *Gutierrezia sarothrae* (Pursh) B. & R. The gray plant is a sagebrush, *Artemesia frigida* Willd.

of stone is put over the main pit. The chinks are stuffed with old corn husks and dirt, and over all there is heaped about a foot of loose earth. The corn is left thus to bake all night, and the party disperses to spend the time in rabbit hunting and storytelling.[2]

Very early the next morning, even before daybreak, the owner goes to the oven, clears away the covering of earth and husks, and removes the stone lid. Then, before taking out a single ear, he stands erect facing east, and as the first light of dawn appears he calls out an invocation to the cloud people (generalized deities who represent dead ancestors). *Na nanivak mongwit, itanamu!* he shouts. *Peo nuswisa huvamu! Pai halaikyang kyango!* ("From all directions come, chiefs, our fathers, all together! May you eat with happy hearts!")

As soon as he has completed his invocation to the gods the owner jumps into the hot, steaming pit and begins to throw the baked ears out on the ground. By this time the other members of the party are generally awake, and one or two at a time they come down from the camp to the oven and begin to husk the corn which has been removed from the pit. During this operation care is taken not to break any of the stems, since they are necessary for bunching the corn together later on. As they work, the huskers eat freely of the hot ears, and they are also privileged to set aside as a reward for their labor the choicest ears they handle. Although no limit is set, it is customary for each worker to take only ten or a dozen ears in addition to those

[2] At a cornbake in which I participated in September, 1933, part of the time that the corn was baking was devoted to storytelling. One of the myths recited by my host's father was particularly interesting.

"Long ago there lived at Oraibi a couple whose happiness was marred by the husband's infidelity. The wife grieved constantly over the situation, but when sweet-corn baking time came, she accompanied her husband into the field. While he was busied with the preparation of the corn-mother prayer offerings, she quietly withdrew and began to dress in her bridal garments. Just as it came time to throw the corn into the hot pit she reappeared and called out hastily, 'Wait, wait till I jump in, then you can throw the corn in after me!' Before anyone realized the full significance of her words, she leaped into the oven and was burned to death."

There are two endings to this little myth. In one version it is said that the cornbake was broken up by the woman's suicide, but the other holds that it was carried out to its conclusion in order that the spirit of the dead woman might have the corn that would have been her due had she remained alive. Everyone agreed that the suicide had been performed in this manner to bring reproach on the husband, so that he would never again get the full enjoyment out of baking sweet corn that every Hopi experiences.

which are eaten on the spot. This custom is part of a Hopi convention that baked sweet corn is anyone's property until the moment that it is bunched and hung on a rack outside the house to dry.[3]

As the husking proceeds the workers ultimately come upon the corn prayer sticks, or corn "mothers," which had been so carefully prepared on the preceding day. When these are husked, the inserted prayer offerings are removed and saved by the owner, but the ears themselves are promptly consumed by the lucky finders. As soon as time permits, the owner takes the prayer offerings to his fields and there deposits them a few inches below the surface, with the breath lines extended toward the east.

When the entire content of the oven has been removed and when all the ears have been husked, the baked sweet corn is loaded into a wagon and the whole party starts for home. Upon arrival in the village the corn is speedily unloaded and the owner's wife promptly fills several trays, which are sent to various neighbors. In this way the recipients are made aware of the fact that a new load of sweet corn has just been brought into the village and that their services are requested by the owner's household. As soon as possible, therefore, the women assemble at the house in question, each one bringing with her an awl fashioned from the front upper leg bone of a sheep. With this implement a hole is bored through the stem of each ear, and a string made of yucca fiber is passed through it. These strings are made by knotting two yucca leaves together at the bases, with the thorny tips left free for convenience in threading. About twenty-five or thirty ears are generally bunched together on one string, the entire cluster being known as *hotumni*. The bundles are then hung on racks outside the house to dry in the sun, after which they are stored away for winter use. From this point on they are the owner's private property.

Baked sweet corn is prepared in several ways. It may be softened by boiling, and eaten on the cob, or else the dry kernels are shelled and ground into a meal known as *tosi*. This meal is sometimes eaten plain, but more frequently it is made into a dough called *qömi*. In this form it is a favorite gift on ceremonial occasions, and,

[3] In keeping with this convention all who happen to pass by while the corn is being conveyed into the village are invariably invited to help themselves; and it is noteworthy that the plural form *nunusa* ("eat") is used even in addressing single individuals. This is explained to mean that the cloud people are automatically included in every invitation.

when shaped into a large brick and proffered under special conditions by a girl to an eligible male, it serves as an offer of marriage.

The account here given is based on the procedure customarily followed at Oraibi on Third Mesa. In general, similar customs prevail at the other Hopi villages, but there are doubtless many variations in regard to particular details. For example, in describing sweet-corn baking at Second Mesa Beaglehole notes that only two ritual corn packets are prepared and that they are called "Mother Corn" and "Father Corn."[4] When these are removed from the baking oven each worker takes a mouthful from the Father Corn cob, but the Mother Corn is carried back to the village to be shared by the owner's household group. One or two other differences are described by Beaglehole, but on the whole the pattern is the same for both mesas.

There is a good deal of archaeological evidence to support the belief that baking various foods in earth ovens is an ancient and widespread custom among the Pueblos. In fact, in the closing years of the nineteenth century Victor Mindeleff (5, pp. 162–163) came to the conclusion that "most of the cooking of the ancient Pueblos was probably done out of doors, as among the ruins vestiges of cooking pits, almost identical in character with those still found in Tusayan [a former name for the Hopi region], are frequently seen." It should be noted that Mindeleff has reference to cooking pits which were used not for baking sweet corn but for the preparation of a corn-mush pudding known as *pi-gummi*, or *pikami*,[5] but the ovens which he pictures (5, p. 163) are structurally comparable in most respects to those used for sweet corn.

In other parts of the Pueblo range Fewkes found similar pits. Both at Kintiel (4, p. 128) and at Four-Mile Ruin (4, p. 139) Fewkes reported "several cysts . . . which were filled with ashes and charred wood. These are interpreted as suburban ovens . . . [which] indicates that cooking was done in the open, just as is the case with certain kinds of food in modern pueblos." Fewkes likewise noted (3, p. 107) "a cluster of communal ovens" at the ruin of Heshotauthla on the Zuñi reservation. These were built of stone and were constructed with chimney-like flues.

[4] For a summary of Second Mesa procedure in baking sweet corn see Beaglehole (1, p. 44).

[5] For a description of *pikami* preparation see Beaglehole (1, p. 66).

In 1930 Dr. Frank H. H. Roberts (6, p. 44) also found a number of out-of-door firepits near Zuñi. These, too, were lined with stone and closely resemble the *pi-gummi* ovens described by Mindeleff and Fewkes. According to Roberts (6, p. 45), his Zuñi workmen were unfamiliar with the *pi-gummi* type of oven, which seemed strange in view of its frequent occurrence in ruins on their reservation. On the other hand, Roberts notes that "the Zuñi continue to roast green corn, in the husks, in deep pits. . . ."

The Zuñi custom of corn roasting furnishes an interesting comparison with Hopi practice. According to Cushing's account (2, pp. 204 ff.), the Zuñi use a cone-shaped pit somewhat similar in principle to the Hopi ovens, but whereas the latter bake sweet corn the Zuñi are said to bake "such corn as gives no promise of ripening." Apart from this basic difference, the procedure follows a comparable pattern for both tribes. The Zuñi first bring the immature unhusked ears to the oven, where a fire is kept burning all night. Then, before they are thrown into the heated pit, the leader of the activity selects a sturdy corn stalk and two fine ears, which are promptly stripped of their husks. The leader lays one ear against the stalk, and from the other he chews the kernels, spraying the pulp over the entire heap of corn. He then places the bare cob by the side of the full ear and binds both to the stalk. After a brief prayer this offering is dropped into the glowing oven and the rest of the corn is hurriedly thrown in, covered with green husks and stalks, and sealed with a mound of damp earth. When the oven is opened the next day the baked corn is removed, but instead of being husked on the spot, as is done among the Hopi, it is carried to the village, and after being husked in the owner's house is braided in long bunches and hung up to dry.

Many other details, such as the payment of workers and the "gorging" that takes place while the baked corn is being brought into the village, support the impression of close similarity between Zuñi and Hopi methods of baking corn. In the light of all the evidence, therefore, Hopi sweet-corn baking may best be considered part of a general Pueblo pattern which seems to have been operative in the Southwest since ancient times.

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PALEOBOTANICAL STUDIES IN MICHIGAN

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THE existence of fossil plants in Michigan has been known for a long time. Among the collections in the Museum of Paleontology of the University of Michigan are specimens obtained many years ago by Bela Hubbard and Alexander Winchell from coal mines or quarries in the vicinity of Jackson. Though the greater number of them are indeterminate, they represent for the most part medullary casts of *Cordaites* and *Calamites*. In 1874 Leo Lesquereux described as land plants some objects from the Silurian near Monroe, but the remains are fragmentary and indefinite and are not accepted as constituting satisfactory evidence of the existence of terrestrial vegetation during that period. In his *Coal Flora*, published in 1880 and 1884, Lesquereux makes no reference to fossil plants from Michigan, although this work was intended to be a comprehensive treatment of the Carboniferous floras of the United States as they were then known. In 1876 Rominger reported silicified wood from the Antrim shale.

If we disregard the supposed bacterial and algal remains described by Walcott from the pre-Cambrian of the Lake Superior region, and the more recently noted but highly problematic vegetable life in the Upper Peninsula, recognizable plant fossils are confined mostly to the Squaw Bay limestone, the Antrim shale, the Saginaw formation, and the Woodville sandstone.

Very few plant types are known from the Antrim shale. *Callixylon* is the only positively identifiable form with known affinities, although a specimen probably belonging to *Bothrodendron* was described by Miss Inez M. Clark in 1934.[1] *Callixylon* occurs in the shale as sections of large silicified trunks, some of which must have attained a diameter of two or three feet. Several such specimens have been recovered from the quarry at Paxton, west of Alpena. Preservation

[1] Clark, Inez M., "Two New Paleobotanical Records for the Antrim Shale of Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 19 (1933) : 59–64. 1934. Unfortunately the figure of *Bothrodendron antrimense* on Plate III is inverted.

of the cell structure is excellent, and splitting reveals, even to the unaided eye, an appearance which, except for the brownish black color, is characteristic of that of recent wood. Fragments of *Callixylon* from the Antrim of Michigan or Ontario occasionally occur in the glacial drift in the southeastern part of the state.

It should be noted in this connection that *Callixylon* is characteristic of this middle Paleozoic black shale wherever it is exposed. It occurs in the Antrim at Kettle Point, Ontario, in the Huron shales of northern Ohio, in the Ohio and New Albany shales wherever they are exposed in Indiana, Ohio, and Kentucky, and in the Chattanooga shale of Tennessee. Microscopic examination of the silicified wood shows that *C. Newberryi,* the common species in Indiana, exists in the Antrim also. The vertical range of *Callixylon* is undetermined, but with the exception of its presence in such shales as the Antrim, New Albany, and others, the age of which has been the subject of considerable dispute, the genus has never been found beyond the limits of the Upper Devonian. In central and western New York it ranges from the top of the Genesee shale to the Cattaraugus, but never as high as beds of undisputed Mississippian age, such as the Pocono or the Kinderhook, or any of the lower Carboniferous horizons of Europe. In New York and Pennsylvania it occurs with *Archaeopteris,* a fern-like plant characteristic of the Upper Devonian the world over.

The plant fossils in the Antrim most likely to arrest attention are long slender impressions marked with prominent cross lines and covered with a thin layer of finely fractured coal. These impressions are commonly from one to three inches wide, but narrower and wider specimens are frequent. Their length is indeterminate, since they are limited to the diameter of the shale slabs, which is seldom more than three feet. Because of the prominence of the cross lines these curious fossils were originally placed in the genus *Calamites,* but later transferred to *Pseudobornia.* Positive evidence exists that at least some of them belong to *Callixylon Newberryi.* Most of them, however, are indeterminate. Satisfactory proof has recently been secured which shows that, whatever their affinities may be, they are not jointed stems of the bamboo fishing-pole type, as is suggested by the prominence of the cross lines, but, rather, pieces of split and broken driftwood which had become transversely cracked by frequent wetting and drying previous to fossilization. Some of them may represent *Callixylon,* or any other woody plant, since

strips of oak bark split in exactly the same manner have been observed.[2]

Passing reference should also be made to the familiar but problematic fossil *Sporangites huronensis*, a small, almost microscopic, spore-like object of which little more is known than when it was originally described by Sir William Dawson many years ago. At places these small amber-colored bodies exist in such numbers that they impart a brownish gray color to the shale.

The coal flora of Michigan has always been regarded as a meager one, and when it is compared with floras of corresponding age in Ohio, Illinois, Pennsylvania, and other states this supposition proves well founded. David White referred to this sparse flora, stating, however, that it is sufficient to indicate a place high in the Pottsville. Two lists of his determinations are included in state geological survey publications of 1902 and 1908. Forty-five forms are listed from eleven localities, but some of the specific names are followed by an interrogation mark and other forms are determined only to genus. Until recently these two lists, which are merely annotated tabulations, were the only published information pertaining to the flora of the Michigan Coal Basin.

This reputed meagerness of the coal flora is in direct relation to the limited vertical and lateral extent of the coal-bearing formation itself, and is not due to any appreciable lack of plant material in the shales interbedded with the coal seams. In direct contrast to the small amount of material that may be collected from various localities near Grand Ledge, St. Charles, and Saginaw, the relative number of species that may be obtained is often surprisingly large. In the collections of the Museum of Paleontology of the University of Michigan the coal flora is represented by only a few hundred specimens, but from this number, thirty-five typical Pennsylvanian species have been determined and four new ones described.[3] Moreover, this number probably represents only one half or less of the total number of species in the collection. From the number of species represented in it we may gain some notion of the relative productivity of the shales of the Michigan coal series if we compare a collection, recently

[2] Arnold, C. A., "The So-called Branch Impressions of *Callixylon Newberryi* (Dn.) Elkins & Wieland and the Conditions of Their Preservation," *Journ. Geol.*, 42 : 71–76. 1934.

[3] Arnold, C. A., "A Preliminary Study of the Fossil Flora of the Michigan Coal Basin," *Contrib. Mus. Paleontol., Univ. Mich.*, 4 : 177–204. 1934.

reported from southwestern Pennsylvania, which contains eighteen thousand specimens but in which only fifty-five species were recognized. Relatively speaking, the flora of the Michigan Coal Basin is not a meager one, but contains a wide range of Pennsylvanian types representing most of the larger plant groups.

Mention of all the plant types of the Michigan coal flora would be out of place here; only those having some special significance will be discussed. It should be noted, however, that there is in the flora an abundance of arborescent forms, such as *Calamites*, *Cordaites*, and *Lepidodendron*. Some of the ironstone nodules belonging to Cycle "A" of W. A. Kelly at Grand Ledge are made up largely of the compacted slender, strap-shaped leaves of *Cordaites*, and pressed between them are broad-winged, platyspermic seeds of the *Samaropsis* type. *Calamites* is represented by foliage, strobili, and pith casts, the latter being especially abundant in the Woodville. Several species of *Lepidodendron* are known. The remains consist of impressions of the trunk surfaces, leafy twigs, spores, and structurally preserved cones of the *Lepidostrobus* type.[4] The cones are rarely observed in the petrified state in North America. Two or three species of *Sigillaria* are present. *S. scutellata* has been observed in the quarry of the Grand Ledge Face Brick Company, and this is the only known occurrence of this common middle Carboniferous European species in America. *Stigmaria*, the rootlike organ of both *Lepidodendron* and *Sigillaria*, occurs in quantity, but merits no comment other than that pieces of it are sometimes found in the glacial drift. Professor Bartlett has described a variety of lepidodendroid spore types from the coal pebbles of the glacial drift.[5]

The pteridosperms and the ferns are represented by several familiar Carboniferous leaf genera as *Neuropteris*, *Alethopteris*, *Mariopteris*, *Sphenopteris*, *Odontopteris*, and *Megalopteris*. The last is known only in North America, where, according to David White, it is characteristic of the Conoquenessing stage of the upper Pottsville. It is also known from Iowa, Illinois, Indiana, Ohio, West Virginia, and New Brunswick.

Megalopteris has large bifurcated fernlike foliar organs, which

[4] Arnold, C. A., "A Petrified Lepidophyte Cone from the Pennsylvanian of Michigan," *Am. Journ. Bot.*, 17 : 1028–1032. 1930.

[5] Bartlett, H. H., "Fossils of the Carboniferous Coal Pebbles of the Glacial Drift at Ann Arbor," *Pap. Mich. Acad. Sci., Arts, and Letters*, 9 (1928) : 11–28. 1929.

sometimes reach a length of one foot. Extending lengthwise along each lobe of the lamina is a prominent midvein, from which closely spaced, dichotomously forked veinlets depart at angles ranging from 45 to 90 degrees, depending upon the species. The largest and most spectacular species is *M. Dawsoni,* which is abundant in the ironstone nodules of Cycle "A" at Grand Ledge. Leaf fragments more than two inches broad have been found. Occurring with it is *M. Kellyi,* a species recently described, which may be distinguished from *M. Dawsoni* by its slightly smaller size and by the lateral veins which extend to the margin, at right angles to the midvein.

The rather constant association of *Megalopteris* and broad-winged seeds of the *Samaropsis* type has been observed upon several occasions, and although they have never been found in organic connection, there is a certain amount of circumstantial evidence that they belonged to the same plant.[6]

Although the plant remains of the Woodville (or, more specifically, the Eaton) present a different aspect from those of the underlying Saginaw, the apparent differences are due to preservation. The remains are largely sandstone casts of trunks and roots, with very little leaf material except *Cordaites.* Preservation took place under an entirely different set of conditions during the time of deposition of the Woodville, but there is no reason to suppose that a markedly different flora existed then. The species of *Calamites, Cordaites,* and *Lepidodendron* appearing in the Woodville are not greatly different from the Saginaw species, and since no typical Permian species have been found, the suggestion from the stratigraphy of the beds that they belong to the Permo-Carboniferous is scarcely supported by the flora. However, the expression of a final opinion must wait for further evidence.

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[6] White, D., "Megalopteris and the Giant Winged Cardiocarps," *Bull. Geol. Soc. Am.,* 44: 213. 1933.

A STUDY OF VEGETATIONAL INVASION AND SUCCESSION ON A DENUDED AREA OF THE CRANBROOK ESTATE, BLOOMFIELD HILLS, MICHIGAN

MARJORIE T. BINGHAM

FOR a number of years a part of one of the moraine ridges within the area of the Cranbrook estate at Bloomfield Hills, Michigan, was used as the local source of gravel. When gravel for building purposes was no longer needed, the pit was abandoned. Since considerable excavating had been done in removing the gravel, the site was used as a dumping ground. In a short time, however, it became evident that this practice was undesirable. Consequently in the summer of 1934 the refuse was cleaned out and the pit abandoned.

It occurred to the director and the botanists of the Cranbrook Institute of Science that this freshly denuded area would afford an interesting study of vegetational invasion and succession. On October 1, 1934, the study was begun. (See Pls. I–II.) The soil of the sides of the pit is sandy clay and gravel; the floor consists of cinders, sandy clay, a mixture of broken glass and scrap tin, with occasional small areas of granular cork.

On the rim were well-established meadow species, such as *Asclepias syriaca* L., *Poa pratensis* L., *Solidago canadensis* L., *Lespedeza hirta* (L.) Hornem., and *Trifolium pratense* L.; included among the arborescent species were *Robinia Pseudo-Acacia* L., *Salix Babylonica* L., *Acer Negundo* L., *Rhus typhina* L., and *Pyrus Malus* L. Of the woody plants mentioned some are native; others are orchard survivals from early farming days; some are introduced.

Twelve permanent meter quadrats were established on the floor and the sides of the pit. Each was marked with four two-by-two-inch wooden pegs driven well into the ground. Into one peg of each plot were hammered tacks three-fourths inch long of a number cor-

responding with the number of the plot, to facilitate subsequent recognition. Numbering of plots began with the first quadrat on the floor of the pit at the left and proceeded in orderly manner toward the right. Species were listed from each of the 12 plots. Each plot was photographed and panoramic views were taken of the entire pit.

To give a more comprehensive picture of invading vegetation 200 additional meter quadrats were chosen at random from all parts of the pit, beginning at the lower left and proceeding in order to the right. Random floor plots were numbered 1–77. Random plots 78–200 were on the sides of the pit. Plot 78 was at the left; plot 200, at the extreme right of the pit. Species from the 200 random and the 12 permanent plots were listed and charted to show the distribution and frequency of species by plots.

Vegetation was rather sparse throughout, as the photographs show. Nevertheless, the total listing gave 85 species, 69 genera, and 31 families. The frequency list of families indicated Compositae leading with 14 representatives. *Solidago canadensis* L. was the most frequent species, with 116 plot occurrences.

On October 1, 1935, a second listing of species was made. The same method was used as in 1934. The 200 random plots, however, from the very nature of their being random plots, were not identical with the 200 plots listed in 1934. Nevertheless, they correspond closely, since each year the listing began at the same point, namely, the floor of the pit at the left, and proceeded to the right. As in 1934, the floor plots were 1 77. Plots 78–200 were on the slopes of the pit.

The listings of 1935 revealed astonishing changes, as did a comparison of the plot and panoramic photographs with those taken from identical positions twelve months before. (See Pls. III–V.) Charted data indicate fewer plant families and fewer genera in 1935–36 than in 1934 35, but an increase in the frequency and dominance of certain of these genera. Photographs show a much denser growth and a very definite and well-marked wall of vegetation advancing up the slopes of the pit and stopping abruptly where the steepness of the slope becomes a deterring factor.

As in 1934, the distribution of species was determined; a record was also taken of the dominant species in each plot. The chart for 1935 indicates the total number of species to be 69; total number

of genera, 55; total number of families, 23. In 1935 there were 16 fewer species, 14 fewer genera, and 8 fewer families than in 1934. Compositae were again the leading family, this time with 16 species represented. *Lactuca scariola* L. was the most abundant of all species. It occurred in 109 plots and dominated 58 of them.

No record of dominance in plots was made in 1934 because the vegetation, though varied, was universally sparse.

Although vegetation was more abundant in 1935 it was more restricted in its range, taxonomically speaking. This was due in part to the disappearance in 1935 of certain cultivated forms such as *Lycopersicum esculentum* Mill., *Brassica Rapa* L., *Lobularia maritima* (L.) Desv., and *Cucurbita pepo* var. *ovifera* Bailey, which were present as relicts of the Cranbrook dump in 1934.

COMPARATIVE LIST OF SPECIES IN THREE OF THE TWELVE PERMANENT METER QUADRATS

Asterisks designate species present in both years; dominant species are indicated by capitals and small capitals.

Plot 1

1934	*1935*
Amaranthus blitoides Wats.	*Ambrosia artemisiifolia L.
*Ambrosia artemisiifolia L.	Erigeron canadensis L.
Cirsium arvense (L.) Scop.	Lactuca scariola var. integrata Gren. and Godr.
*Lepidium virginicum L.	*Lepidium virginicum L.
Panicum capillare L.	Melilotus alba Desr.
*Poa pratensis L.	*Poa pratensis L.
Setaria viridis (L.) Beauv.	*Solidago canadensis L.
*Solidago canadensis L.	Trifolium repens L.

Plot 7

1934	*1935*
No vegetation	Achillea Millefolium L.
	Amaranthus blitoides Wats.
	Chenopodium album L.
	Erigeron canadensis L.
	Lactuca scariola L.
	Lepidium virginicum L.
	Melilotus alba Desr.
	Panicum capillare L.
	Salsola Kali var. tenuifolia G. F. W. Mey.

PLOT 8

1934	*1935*
Ambrosia artemisiifolia L.	Erigeron canadensis L.
Barbarea vulgaris R. Br.	LACTUCA SCARIOLA L.
Brassica Rapa L.	Lepidium virginicum L.
Chenopodium album L.	Melilotus alba Desr.
Coreopsis lanceolata L.	Poa compressa L.
Leonurus Cardiaca L.	Prunus sp.
Lobularia maritima (L.) Desv.	Raphanus sativus L.
Polygonum persicaria (L.) Small	*Setaria viridis (L.) Beauv.
Polygonum scandens L.	Sisymbrium officinale L.
Poa pratensis L.	Taraxicum officinale Weber
*Setaria viridis (L.) Beauv.	
Setaria media (L.) Cyrill	
Trifolium repens L.	

SPECIES LISTED IN THE ORDER OF THEIR FREQUENCY

No. of plot occurrences	*1934*	*1935*
116	Solidago canadensis L.	
109		Lactuca scariola L.
94		Melilotus alba Desr.
80		Erigeron canadensis L.
63		Salsola Kali var. tenuifolia G. F. W. Mey.
60	Poa pratensis L.	
56	Panicum capillare L.	
55		Lepidium virginicum L.
54		Poa pratensis L.
52	Chenopodium album L. Salsola Kali var. tenuifolia G. F. W. Mey.	
44		Panicum capillare L.
39	Setaria viridis (L.) Beauv.	
37	Ambrosia artemisiifolia L.	
34	Achillea Millefolium L.	
31		Lolium perenne L.
30		Ambrosia artemisiifolia L.
28	Taraxicum officinale Weber	
27	Trifolium repens L.	Achillea Millefolium L.
25	Lepidium virginicum L.	
24	Polygonum aviculare L.	Setaria viridis (L.) Beauv.
23	Lolium perenne L.	
22	Amaranthus blitoides Wats.	
21	Erigeron canadensis L.	Solidago canadensis L.
19		Sisymbrium officinale L.
17	Eragrostis megastachya (Koehler) Link Medicago sativa L.	Trifolium repens L.

No. of plot occurrences	*1934*	*1935*
16	Amaranthus hybridus L. Rumex crispus L.	
13	Echinochloa crusgalli (L.) Beauv. Polygonum persicaria (L.) Small	Eragrostis megastachya (Koehler) Link. Solidago graminifolia (L.) Salisb. Taraxicum officinale Weber
12		Setaria glauca (L.) Beauv.
11	Digitaria sanguinalis (L.) Scop. Setaria glauca (L.) Beauv.	
10	Capsella Bursa-pastoris (L.) Medic.	Fragaria vesca L.
9	Coreopsis lanceolata L.	Echinochloa crusgalli (L.) Beauv. Rumex crispus L. Verbascum Thapsus L.
8	Cirsium arvense (L.) Scop. Fragaria vesca L. Verbascum Thapsus L.	
6	Lactuca scariola L. Leonurus Cardiaca L. Lespedeza hirta (L.) Hornem. Nepeta Cataria L. Sisymbrium altissimum L.	Agrostis alba L. Medicago sativa L. Potentilla recta L.
5	Lepidium densiflorum Schrad. Robinia Pseudo-Acacia L.	Arctium Lappa L. Cirsium arvense (L.) Scop. Lactuca scariola var. integrata Gren. and Godr. Plantago major L.
4	Asparagus officinalis L. Chenopodium hybridum L.	Amaranthus graecizans L. Apocynum sp. Chenopodium album L. Polygonum persicaria (L.) Small Robinia Pseudo-Acacia L. Rumex Acetosella L.
3	Amaranthus Palmeri Wats. Brassica Rapa L. Chrysanthemum Leucanthemum L. Cucurbita maxima Duchesne Equisetum hyemale L. Ipomoea purpurea (L.) Roth Lobularia maritima (L.) Desv. Lychnis alba Mill. Plantago major L. Potentilla monspeliensis L. Psedera quinquefolia (L.) Greene Rhus typhina L. Stellaria media (L.) Cyrill Trifolium reflexum L.	Amaranthus blitoides Wats. Asclepias syriaca L. Bromus commutatus Schrad. Daucus Carota L. Nepeta Cataria L. Phleum pratense L. Polygonum aviculare L. Psedera quinquefolia (L.) Greene Raphanus sativus L.

SUMMARY

In 1934 the list of vegetation in 212 meter quadrats in a denuded area, formerly the Cranbrook gravel pit, revealed 85 species, representing 69 genera of 31 families. Compositae, with 14 species represented, led in family frequency. *Solidago canadensis* L., with 116 plot appearances, occurred most often. Gramineae proved a close second with 10 representatives, headed by *Poa pratensis* L. with 60 plot occurrences.

The vegetation charts for 1935 showed Compositae still the most frequent and the dominant family, with 16 species represented. *Solidago canadensis* L., however, was no longer the leading species. *Lactuca scariola* L. was dominant in 58 plots and, with occurrences in 109 plots, led all species. Again Gramineae were a close second, with 12 species; nevertheless, *Poa pratensis* L., the leading species in 1934, dropped to sixth place with only 55 plot occurrences and was supplanted in the frequency list of species by *Melilotus alba* Desr., which was recorded in 94 plots.

CONCLUSIONS

Regardless of slight differences in the number of species present in 1934 and 1935 the same eight plant families lead the list of invaders. The Compositae, the leading family, maintained each year an identical margin over the Gramineae. Seeds of most dominants are windblown. Others depend on animals.

Notwithstanding the general recognition of 95 per cent of all species listed as particularly noxious weeds, they should be seriously regarded as active and persistent agents in erosion control.

Cranbrook Institute of Science
Bloomfield Hills, Michigan

FIG. 1. Panoramic view of gravel pit in 1934

FIG. 2. Panoramic view of gravel pit in 1935

FIG 1. General view of gravel pit, looking west, 1934

FIG. 2. General view of gravel pit, looking west, 1935

FIG. 1. Permanent plot I, 1934

FIG. 2. Permanent plot I, 1935

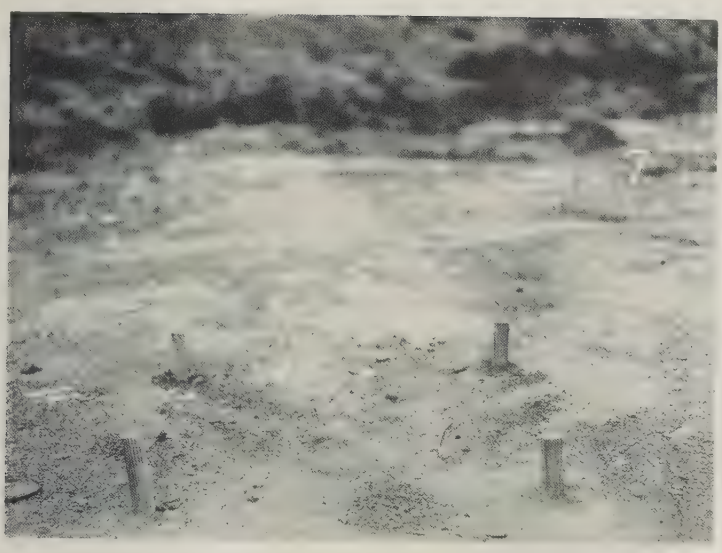


FIG. 1. Permanent plot 7, 1934

FIG. 2 Permanent plot 7, 1935

FIG. 1. Permanent plot 8, 1934

FIG. 2. Permanent plot 8, 1935

ANATOMY OF THE INFLORESCENCE OF *URGINEA MARITIMA* (L.) BAKER

DOROTHY CHAPMAN CARPENTER

INTRODUCTION

URGINEA MARITIMA (L.) Baker, or sea onion, is a member of the Liliaceae. It is distinguished from its close relative, *Scilla*, in Engler and Prantl (4) by its compressed, angular seeds and deciduous perianth segments; in *Scilla* the seeds are conical or obovate and the perianth persistent. *U. maritima* is a perennial with a large bulb somewhat immersed in the soil. At its base is a stem plate which is in part a meristematic region, giving rise to leaves and flower stalk and to a fibrous root system. The leaves as they emerge from the bulb are round and solid for varying lengths; these split and are flat during further growth (2). In *U. maritima*, as in such Monocotyledones as Muscari, Ornithogalum, Scilla (3), Erythronium (5), Tulipa, and many others (1), there is also an asexual reproduction by bulbils produced vegetatively on the scale surfaces.

DESCRIPTION

A single flower stalk is produced annually from the stem plate of a *U. maritima* plant. At its tip are the numerous green and white flowers in a terminal raceme, each flower being borne singly on a pedicel which comes off from the scape just above a bract. When young, the scape grows extensively at the base, reaching as much as one to one and two-thirds meters in length. During this time the flowers are closed buds upon short pedicels, and compose a closely compressed head covered by the bracts. While a plant was in this stage sections were made of the flower stalk at its basal, central, and top regions.

At the top of the flower stalk just below the terminal raceme the peduncle is narrow, and most of the tissue is parenchymatous. It has eighteen large vascular bundles, round in cross section and arranged irregularly. The endarch xylem is innermost, and the phloem

contains sieve tubes and companion cells. Midway of its length the scape is larger in circumference. Seven large bundles are in the center and seven more large ones outside them and alternating with them. At the base the scape is round and still larger, with three series of bundles. Of these, six are long, narrow collateral bundles arranged in a ring around the center. Six smaller bundles alternate with the larger ones, outside them, and nineteen smaller ones are still farther outside. A fifth of the way in from the epidermis a sheath of small compressed parenchymatous cells extends around the stalk (Fig. 1). The epidermis is thin-walled, and no stomata are present.

Sometime in May (in the greenhouses in Ann Arbor) after several weeks of basal growth, the scape begins to elongate at the flower end. At the same time the pedicels grow rapidly from the bottom of the raceme upward, and the lowermost flowers open. Not more than four to eight flowers are ordinarily open at one time (Fig. 2); the top portion of the raceme is still composed of tightly closed buds (Fig. 3). Flowering in a plant may last until late July, the upper portion of the inflorescence continuing to elongate as the flowers open until it reaches two thirds of a meter or more in length.

In the Urginea flower the three sepals and three petals are very much alike in appearance, all white with a green stripe running through the center, but the petals are slightly shorter and narrower than the sepals (Fig. 4). The six stamens are opposite the petals and sepals, to which they are attached by their extreme lower portions (Fig. 5). The filaments are narrow at the anther end, but broaden out into white, wide, fleshy basal structures. They reach to the top of the one-parted style of the superior ovary (Figs. 6 7). The style is long and thin and has numerous hairs at its tip (Fig. 8).

The ovary is composed of three carpels, and the ovules have axial placentation (Figs. 9–10). Dissection of one carpel longitudinally shows the nine to twelve ovules and their points of attachment (Fig. 11). The ovules are white and translucent, faintly bilobed, and narrow but slightly at the base (Fig. 12). From one to four seeds mature in each locule, the remaining ones aborting. The fruit is a capsule, dehiscing loculicidally along the middle of each carpel. It is brown and dry when ripe, with no remnants of the style, but with the basal portions of the calyx, corolla, and stamens still attached (Fig. 13).

The ripe seed is about five by three millimeters and is black and

sharply three-angled (Fig. 14). With the seed coats removed the seed is white and shiny and three-angled, and the greater part is endosperm; the micropyle is at one end and the hilum at the other (Fig. 15). The endosperm cell walls are very thick, angled, and perforated by large pore canals which permit the passage of materials from cell to cell (Fig. 17). The embryo is a straight, cylindrical, threadlike body and is embedded upright in the endosperm (Fig. 16).

The bracts are white, with a narrow green longitudinal stripe, and are from eight to nine millimeters long and 1.5 millimeters wide at the widest point. On the under surface are a few scattered stomata; the lower epidermis is like that of the leaf except that the smaller ovoid cells are lacking. No stomata are found on the upper surface, where the epidermal cells are rectangular but shorter and wider than those on the lower surface. The tip of the bract in cross section is round and has one central bundle. Farther down a cross section shows two thin projections, the sides of the bract, coming off from the round tip; the central bundle is much larger and the xylem is clearly innermost. Ovoid or rhomboidal crystals of various sizes fill numerous large cells; chloroplasts are present in many of the central cells. The anatomy is the same until midway down the bract, where the thinner side projections become much expanded as the bract widens out within a short space.

Serial sections were made of the pedicel from its base up through the ovary and style after the calyx, corolla, and stamens had been removed. At its base occur twelve bundles irregularly arranged, and the greater part of the tissue is parenchymatous. In the epidermis a large number of stomata open into air spaces. The two outermost layers of cortical cells are loosely arranged, with many air spaces, and contain numerous chloroplasts. They and the three or four layers directly inside them are of much larger cells than the remainder of the pedicel. Large cells containing raphides, or shorter, thicker crystals, are frequent.

The endarch xylem is innermost, and sieve tubes and companion cells are present in the phloem. A short distance up the pedicel two adjoining bundles unite. The general structure is unchanged up to the receptacle except that there are comparatively few stomata. Where the pedicel joins the receptacle the vascular bundles split up into a number of smaller ones. No stomata, intercellular spaces, or chlorophyll-bearing cells are found at this level. The small bundles

give off the vascular strands to supply the flower parts. Five strands go to each sepal, three to each petal, and two to each anther. Just above this level seven of the small bundles are in the form of a circle, with the remaining six outside them. From the level of union of the top of the pedicel with the base of the ovary the shape of the latter changes gradually from round to roughly triangular, the center of the carpel being the angle. The vascular system is the same except for three wide strands which go off from three central bundles to the "angles" of the triangle. The central bundles are larger than the six outer ones; the latter are composed of but two or three xylem elements and a large amount of phloem.

At a slightly higher level the ovary is triangular. The six outer vascular bundles no longer contain any xylem; they curve sharply toward the outside. The central bundles no longer exist as such; instead a small area in the center is composed of parenchyma cells, similar to those which make up the greater part of the tissue. Around it is a large irregular circle of very small undifferentiated parenchyma and phloem cells with a few scattered tracheids. Above this the three wide vascular strands turn upward sharply at the outer sides, so that in cross section of the ovary they are cut transversely. Directly inside and between them and the center are the three locules. At the lines of union of the three carpels the outer wall of the ovary is indented, and between the center of the ovary and each indentation is a small slit in the tissue. The bundles which lack xylem are in pairs, one on each side of the indentation and split, near the outside of the ovary.

Farther up in the ovary the central vascular area of undifferentiated parenchyma, phloem, and xylem separates into six bundles arranged in three pairs, so that each carpel has one dorsal and two ventral bundles, all with xylem, and free from one another. The locules are larger at this level and contain several mature ovules (Fig. 18). A vascular strand is given off from one of the two ventral bundles in a carpel and extends out through the entire length of an ovule. The indentations in the ovary wall are deeper nearer the top and extend almost to the outer end of the split just inside. The bundles lacking xylem are in pairs on either side of the indentations. Each indentation unites at a higher level with the split inside, separating the carpels still farther. The six ventral bundles, which contain only a few xylem elements, each give off a vascular strand which

curves upward and outward toward a dorsal bundle. The six bundles without xylem near the indentations do not extend so far up in the ovary, and hence have disappeared. The outer portions of the locules are only slightly smaller than they were at a lower level; at a third of their width from the center they narrow suddenly into mere slits, which end in crescent-shaped openings.

Above this level the ovary narrows rapidly; three narrow lobes are joined at the central placental region. The locules are smaller, and only the three crescent-shaped openings in the center remain; the ventral bundles no longer exist. The vascular strands which each ventral bundle gave off to the dorsal bundle of that carpel at a lower level join and turn up and inward, extending almost to the crescent opening. The ovary gradually changes into a style three to four millimeters long and very thin. The three central crescent openings are larger oval slits. Between them and the outside the vascular strands curve directly upward and again appear in cross section. The cells of the style are smaller than those of the ovary; no crystals of any sort occur, nor, as is also true of the ovary, any stomata. The bundles have the endarch xylem innermost.

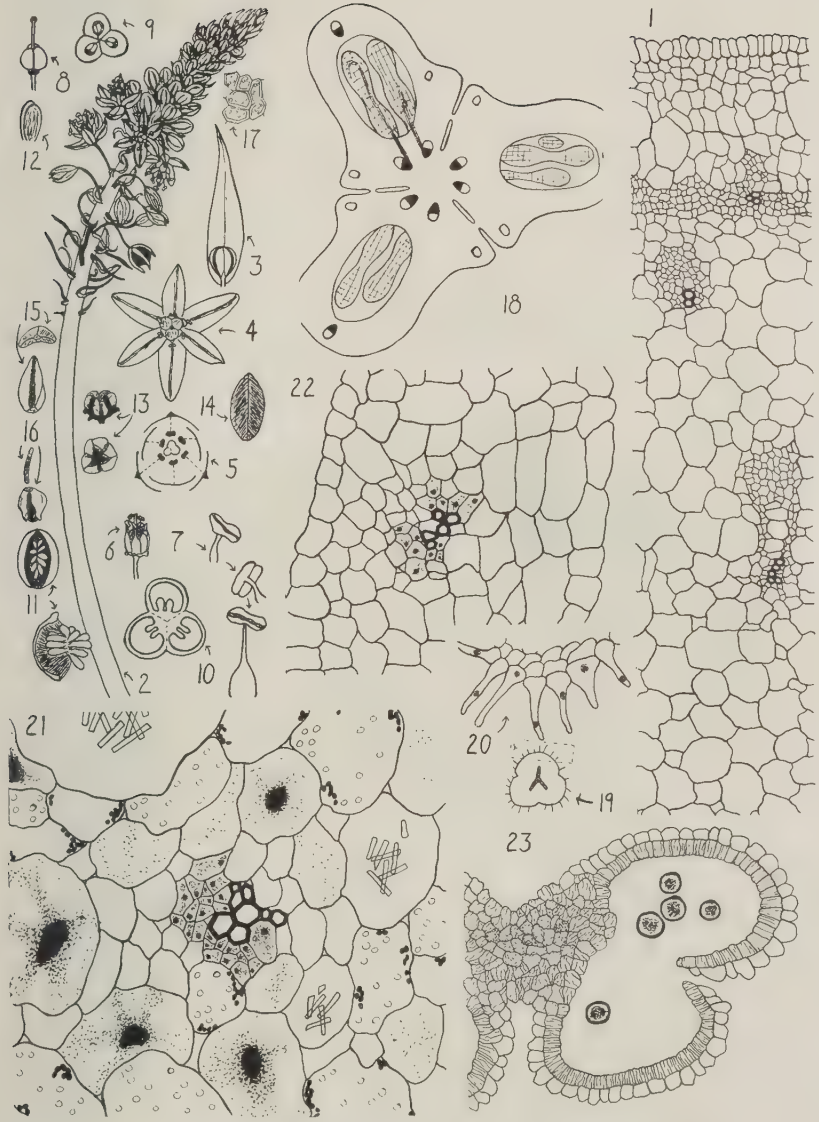
At the center the three slits merge into one. The three bundles, which are very small, contain but a few elements of xylem and phloem. The stigma has a slight indication of the three lobes; the three merged locular slits are small and narrow, and no bundles are in the tissue. The entire stigmatic surface is covered with numerous hairs; over one hundred were counted on a single stigma. They are epidermal in origin and contain conspicuous nuclei (Figs. 19–20). The tissue is entirely parenchymatous and has no crystals; neither chlorophyll-bearing cells nor any stomata are found. The three sepals are white and are about ten millimeters long and four wide at the widest part. There is a longitudinal green stripe one and one-half millimeters wide their entire length, and there are five vascular bundles. On the lower surface, only, a small number of scattered stomata are found; the epidermal layers are similar to those described for the bract. A cross section at the tip shows one bundle; a short distance below this occur three bundles, and still lower five bundles, which continue to the base of the sepal. The middle bundle is much larger than the others; many of the extravascular parenchyma cells contain raphides or small round or large angular crystals (Fig. 21).

The three white petals are of the same shape but slightly shorter

and narrower than the sepals. Each one is about nine millimeters long and three and one-half millimeters wide and has a longitudinal green stripe about one millimeter wide its entire length. Scattered stomata are present on the lower surface, but not on the upper one; the epidermal layers are similar to those of the bract and sepal. The three vascular bundles do not extend quite to the tip of the petal. Cross sections midway down the length of the petal show the thicker mid-region and the thin sides; the cells are large, with numerous intercellular spaces, and contain raphides and many round or angular crystals of various sizes. The central bundle is the largest; the other two are smaller but of the same size.

The six anthers are white with broad fleshy filaments, which are about six millimeters long and one and one-half to two millimeters at the widest region. They are narrow at the base and top, but between are broadly flared; there are no stomata. The anthers are about two and one-half millimeters long and one and one-quarter millimeters wide. A transverse section through the base of the filament shows a wide thin structure with two bundles in the center; the xylem is innermost. The remaining tissue is entirely parenchymatous, and no crystals or chloroplasts are present. Higher up the filament is smaller and almost terete; the two bundles, still with the xylem innermost, curve nearer together, and but the space of one cell remains between the two xylem patches.

The filament is smaller and somewhat oval near its point of attachment with the anther. The xylem of the two bundles has the appearance of one large strand, the bundles having united at the center; the phloem areas are separate, however, and on opposite sides of the xylem (Fig. 22). The vascular tissue curves from the filament to the connective of the anther and extends a short distance into it. No vascular tissue exists above this level; the central portion of the connective region is composed of parenchyma cells. The cells are smaller and contain no crystals or chloroplasts. Within each pollen sac, when ripe, is an epidermal layer of large cells, and, directly inside it, a row of rectangular cells which have numerous bands of lignin on their walls. Cells of this same type also surround the few parenchymatous cells in the connective area and form the remainder of that region (Fig. 23). The mature pollen grains are irregularly spherical, have a smooth exine, and are binucleate.



Inflorescence of *Urginea maritima* (L.) Baker

SUMMARY

1. A single annual flower stalk in *U. maritima* bears numerous green and white flowers in a terminal raceme. Each flower is borne singly on a pedicel which comes off from the scape just above a bract.

2. All bundles of the inflorescence are collateral, with the endarch xylem innermost. There are one bundle in each bract, two in each stamen, three in each petal, and five in each sepal.

3. The general tissue of the petals, sepals, and bracts is parenchymatous, with many raphides and other crystals present. Chlorophyll is found only in the central green-striped regions. The anthers are white with broad fleshy filaments.

4. The ovary is composed of three carpels, and the ovules have axile placentation; from one to four black, sharply three-angled seeds mature in each locule. The fruit is a capsule dehiscing loculicidally along the middle of each carpel.

5. Stomata are present only on the pedicels and the lower surfaces of the bracts, sepals, and petals.

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LICHENS COLLECTED IN THE PORCUPINE MOUNTAINS, NORTHERN MICHIGAN

HENRY TOWNSEND DARLINGTON

THIS paper lists a number of lichens collected by the writer in 1922 and 1923, while engaged in studying the vascular flora of the region. Most of the specimens were collected in T. 51 N., R. 42 W., within a four-mile radius of Carp Lake, Ontonagon County, Michigan. This area contains several important physiographic features, embracing the rocky shore line of Lake Superior, a high rocky ridge paralleling the shore for several miles, prominent hills or knobs such as Government Peak, and Carp River and its tributaries. In this paper the high rocky ridge will be spoken of as the "main range." It consists largely of sandstone, which is weathering off along many steep parts on the south side and forming an extensive line of talus material at the base. The region contains a great diversity of habitats, the most important of which are associated with the Lake Superior shore and the rocky summits of the first range, at approximately one and one-half miles back from the lake. A number of species were found in the primeval forests of hemlock and maple that cover the slopes of the hills.

Apparently the only list of lichens previously published from the region is that of Ruthven, 1906.[1] Thirteen species are recorded, with notes on habitat and locality. In 1931 an ecological survey [2] of the region was published in which a few species of ecological interest were mentioned. These, however, were not definitely listed. The present list enumerates 73 species in 28 genera. It must fall far short of the total number of species of this group to be found in the region. Plants collected in 1922 were identified by the late Dr. Bruce Fink, of Miami University. Those collected in 1923 were named by Joyce

[1] See Adams, C. C., "An Ecological Survey in Northern Michigan," *Geol. Surv. Mich., Ann. Rep. for 1905.* List of lichens by A. G. Ruthven, pp. 75–76.

[2] Darlington, H. T., "Vegetation of the Porcupine Mountains, Northern Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters,* 13 (1930) : 9–66. 1931.

Hedrick, of the University of Michigan, who also arranged the sequence of families and genera. Those species preceded by a star were collected by Ruthven. The detailed list with habitats follows:

List of Species

DERMATOCARPACEAE

*Dermatocarpon miniatum (L.) Mann.

Dermatocarpon miniatum complicatum (Light.) T. Fries. — On vertical rock faces along Lake Superior shore.

ARTHONIACEAE

Arthonia radiata (Pers.) Ach. — On trees.

GRAPHIDACEAE

Graphis scripta (L.) Ach. — On bark of living trees in maple woods.

PANNARIACEAE

Parmeliella microphylla (Sw.) Müll. — On damp vertical cliffs of the main range.

STICTACEAE

Sticta amplissima (Scop.) Rabh. On flat surface of boulders in woods and on bark of arbor vitae; frequent.

Sticta aurata Ach. — On bark of dead hemlock.

*Sticta pulmonaria (L.) Bir. - On ground and mossy logs in shady situations; occasional.

PELTIGERACEAE

Nephroma laevigatum Ach. — On thin soil on boulders.

*Peltigera aphthosa (L.) Willd.

Peltigera canina (L.) Willd. — On ground in forest; frequent.

Peltigera horizontalis (Huds.) Baumg. – On hemlock logs in forest.

Peltigera malacea (Ach.) Funck. — On large boulders.

Peltigera spuria (Ach.) DC. — On ground.

LECIDEACEAE

Lecidea contigua E. Fries. — On sandstone rock at summit of range; frequent.

Lecidea goniophila (Floerke) Schaer. — On sandstone along Lake Superior shore; common.

Lecidea lapicida Ach. — On rock surfaces.

*Lecidea lucida Ach. — On vertical shaded rock faces of the main range.

Lecidea pantherina (Hoffm.) Ach. — Forms white patches on exposed rocks; frequent.

Rhizocarpon disporum (Naeg.) Müll.-Arg. — On rocks along Lake Superior shore.

Rhizocarpon petraeum (Wulf.) Mass. — Common on boulders along Lake Superior shore. This appears to be the pioneer crustose species on rock surfaces along the shore.

CLADONIACEAE

Cladonia alpestris (L.) Rabh.

Cladonia cristatella Tuck. — On dry ground; frequent.

Cladonia degenerans (Floerke) Spreng. — On dry ground along summit of range.

Cladonia fimbriata (L.) E. Fries. — On dry open ground.

Cladonia Floerkeana (E. Fries) Sommerf. — On ground.

Cladonia pyxidata (L.) Hoffm. — Common on talus and on large conglomerate boulders along shore.

*Cladonia rangiferina (L.) Web. — On ground along summit of range; common.

Cladonia squamosa (Scop.) Hoffm. — On conglomerate boulders along Lake Superior shore.

Cladonia sylvatica (L.) Hoffm. — On ground at summit of range and on rocks of talus; also var. *sylvestris* (Oed.) Vainio.

Cladonia turgida (Ehrh.) Hoffm. — On dry ground.

Cladonia verticillata Hoffm. var. cervicornis (Ach.) Flot. — On earth.

Stereocaulon coralloides E. Fries. — Frequent on soil throughout the area.

Stereocaulon paschale (L.) Hoffm. — Very common on dry talus rocks and on summit of main range.

GYROPHORACEAE

Gyrophora Dillenii (Tuck.) Müll.-Arg. — On rocks.

Gyrophora hyperborea Ach. — On rocks at summit of main range.

Gyrophora vellea (L.) Ach. — On damp vertical rock faces of the main range.

PERTUSARIACEAE

Pertusaria leioplaca (Ach.) Lam. & DC. — On arbor vitae; summit of Government Peak.

Pertusaria pertusa (L.) Tuck. — On bark of arbor vitae.

Pertusaria velata (Turn.) Nyl. — Same habitat as preceding species.

LECANORACEAE

*Lecanora cinerea (L.) Röhling. — On sandstone and conglomerate along Lake Superior shore; very common.

Lecanora muralis (Schreb.) Rabh. var. Garovaglii (Koerb.) Tuck. — On red sandstone blocks of the talus.

Lecanora muralis saxicola (Poll.) Tuck. — On rock surfaces.

Lecanora pallida (Schreb.) Rabh. — On trunk of red oak; summit of Government Peak.

Lecanora subfusca (L.) Ach. — On bark of white birches; frequent.

Lecanora varia (Hoffm.) Ach. — On sandstone rocks along Lake Superior shore.

Ochrolechia tartarea (L.) Mass. — On tree trunks.

Candelariella aurella (Hoffm.) Zahlbr. — Common on boulders along Lake Superior shore and on top of main range.

PARMELIACEAE

Candelaria concolor (Dicks.) Arn. — On tree trunks.

Parmelia caperata (L.) Ach. — On surface of trees and rocks.

*Parmelia conspersa (Ehrh.) Ach. — Common on rocks of the talus and on conglomerate along Lake Superior shore where not exposed to wave action.

Parmelia olivacea (L.) Ach. — On trees.

Parmelia perforata (Wulf.) Ach. - One specimen collected on ground in forest.

Parmelia physodes (L.) Ach. — On tree trunks.
Parmelia quercina (Willd.) Vainio. — On maple trees.
Parmelia rudecta Ach. — On rocks along Lake Superior shore.
Parmelia saxatilis (L.) Ach. — On sugar maples.
Parmelia sulcata Tayl. — On trunks of trees.
Cetraria juniperina (L.) Ach. — On living trees; frequent.

USNEACEAE

Ramalina calicaris (L.) Röhling. — Common on sugar maples and overhanging rocks.
Usnea barbata (L.) Wigg. — On bark of trees; common.
Usnea plicata (L.) Wigg. — On dead twigs; frequent.

CALOPLACACEAE

Caloplaca elegans (Link) T. Fries. — This species forms from beautiful yellow bands on vertical rock faces of the main range.
Caloplaca sideritis (Tuck.) Zahlbr. — On sandstone.

TELOSCHISTACEAE

Teloschistes polycarpus (Ehrh.) Tuck. — On dead poplars.

BUELLIACEAE

Buellia parasema (Ach.) De Not. — On sugar maples.
Rinodina Bischoffii (Hepp) Mass. — On rock surfaces along Lake Superior shore.

PHYSCIACEAE

Physcia lithotodes Nyl. — On rocks along Lake Superior shore; occasional.
Physcia obscura (Ehrh.) Hampe. — On damp rock surfaces at summit of range and also on trees; frequent.
Physcia tribacia (Ach.) Nyl. — On trees.
Anaptychia aquila (Ach.) Mass. — On bark.

LEPRARIACEAE

Amphiloma lanuginosum (Hoffm.) Nyl. — On moist vertical rock faces of the main range and in crevices of hemlock bark; common.

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NOTES ON THE MICHIGAN FLORA. VII

OLIVER A. FARWELL

THE plants here listed were collected in Keweenaw, Houghton, and Ontonagon counties, which are in the north-central part of the Upper Peninsula of Michigan, in the region generally referred to as the "Copper Country," and in Oakland, Wayne, and Washtenaw counties, in the southeastern part of the Lower Peninsula. The two groups of counties are about 450 miles apart.

The author is very much indebted to Mr. E. J. Palmer and to Mr. Alfred Rehder, of the Arnold Arboretum, Jamaica Plain, Massachusetts, for the identification of *Crataegus irrasa* and *Lonicera prolifera*, and to Mrs. Agnes Chase and Dr. S. F. Blake, of the Department of Agriculture, for the identification of and information regarding *Sporobolus asper* and *Quizotia abyssinica*. He wishes to express here his appreciation of their valued assistance.

List of Species

EQUISETUM PALUSTRE L. — All works on local floras say of this species: "stems all alike." This condition is true only after the middle of June. The plant grows abundantly almost at my front door, and I have been closely observing it for the past two or three years. The rhizomes, which are five or six lines in diameter, are one foot or more under ground; nodes are about one inch apart and give rise to verticils of branches, which in their turn similarly branch at the nodes, so that a rhizome three feet long and many times branched would give rise to a veritable miniature forest of stems, sterile and branched, fertile and simple, with cones sessile or peduncled and every imaginable intermediate form. The production of new stems continues all through the season until autumn frosts lay the stems low and destroy growth. The first set of stems, all simple and fertile, which appear early in May, would be taken by the casual observer for the fertile stems of *E. arvense*; they are pink, with black sheaths and teeth, somewhat more shining and stouter than those of *E. arvense* and, like them, wither and die

as soon as the spores are shed. The next two or three sets of stems that appear are more or less pink in the upper parts, which die and fall away as the spores are shed, while the lower parts remain green and usually send out one or more sterile branches. It is not until the fourth or fifth set of stems appear that they are green throughout, after which they remain herbaceous and all alike for the rest of the season. Lake Linden, Houghton Co., no. 9682, May 13, 1936, and at various other times until late in August.

Pinus Strobus L., P. resinosus Ait., and P. Banksiana Lamb. — It is a well-known fact that a poor growing season produces a condensed growth of wood in trees of the North Temperate Zone. I have noticed this year (1936) that this is true likewise for the leaves as exemplified in these three species of pine; the leaves of the poor season of growth are much shorter and thicker and suggest hybridization. Samples were collected at Eagle Harbor, Keweenaw Co., as follows: May 10, 1936: *P. Strobus*, no. 11152; *P. resinosa*, no. 11153; *P. Banksiana*, no. 11154.

Thuja occidentalis L. — Commonly called cedar in the Lake Linden district. Staminate flowers are frequently found in full bloom in January. This species forms dense swamps, referred to as "cedar swamps." It is a commercial timber. Lake Linden, Houghton Co., no. 10681, Jan. 24, 1935. On rocky shores, declivities, and such places it produces stunted forms of various hues and shapes. Forms corresponding to the following varieties have been collected or observed:

Var. Woodwardii Spaeth, no. 10673, Nov. 14, 1934;

Var. pumila Beissn., no. 10676, Nov. 14, 1934;

Var. globosa Gordn. Observed in inaccessible places.

Typha latifolia L. var. elatior Graebn., no. 11071.

Typha latifolia L. var. angustifolia Hausskn., no. 11072.

These two varieties are found near Lake Linden, Houghton Co., and were collected on September 7, 1935, along with the typical variety of the species, no. 11070. The three varieties are associated in the same, or in distinct, colonies.

Alisma Plantago-aquatica L. var. **americanum** (R. & S.), n. comb. (*A. Plantago* var. *americanum* R. & S., *Syst.*, VII : 1598. 1830; *A. trivialis* Ph.). — The large-leaved water plantain is frequent at Cliff Mine, Keweenaw Co.: no. 459, Aug. 20, 1886.

Butomus umbellatus L. — Flowering rush. Wayne Co.: Brownstown Township, no. 8742, Aug. 26, 1930; River Rouge, no. 8759, Sept. 9, 1930. Both places are in marshes along the shores of the Detroit River. This species has long been naturalized in the vicinity of Detroit and southward. I am informed on good authority that it was well established before the present century and that it covered acres of marshes at River Rouge before the operations of the Ford Motor Co. in this region reclaimed the marshland and destroyed the better part of the stand. There is nothing to prove or to disprove the belief that the plant was brought over by Cadillac's party more than three centuries ago and that it has been here ever since.

Panicum depauperatum Muhl. var. psilophyllum Fern. — Frequent on sand dunes at Seven-Mile Point, Keweenaw Co.: no. 11338, July 16, 1936.

Phalaris arundinacea L. var. picta L. — The ribbon grass of cultivation is an escape at Lake Linden, Houghton Co., along roadsides and along the shores of Torch Lake: no. 10385, Aug. 27, 1934, and no. 11429, July 29, 1936.

Muhlenbergia diffusa (Muhl.) O. A. F. var. attenuata (Scribn.) O. A. F. — A rare plant in Michigan. Birmingham, Oakland Co., no. 1812½, Aug. 29, 1903.

Sporobolus asper (Mx.) Kunth. (*S. longifolius* [Torr.] Wood). — Along the Michigan Central Railroad tracks at Denton, Wayne Co., no. 9019, Oct. 6, 1931.

Aristida basiramea Engelm. — Dry foothills of the bluffs at Cliff Mine, Keweenaw Co., no. 3911½, Oct. 1, 1914.

Agrostis scabra Willd. var. **keweenawensis** (O. A. F.), n. comb. (*A. hyemalis* var. *keweenawensis* O. A. F., *Mich. Acad. Sci., Ann. Rep.*, 6 : 203. 1904). — This is the variety with awned lemmas, and consequently is the same as Tuckermann's *A. laxiflora* var. *montana*, which name, according to Fernald, is untenable. Rocky shores of Lake Superior, Keweenaw Co., no. 600c, July 1, 1895.

Avena fatua L. Oat. — On the sand beach at the Canal, Houghton Co., where it was rather scarce, no. 8258, Aug. 10, 1928; sandy hills near Lake Linden, Houghton Co., no. 10909, July 16, 1935.

Avena fatua L. var. glabrata Peterm. — Associated with the species at the Canal, Houghton Co., no. 8258a, Aug. 10, 1928.

Danthonia spicata (L.) Beauv. var. pinetorum Piper (*D. thermalis*

Scribn.). — Another western plant found in the Lake Superior district. Keweenaw Co.: Eagle Harbor, no. 6632, Aug. 29, 1923; Copper Harbor, nos. 8491, July 14, 1929, and 11275, July 14, 1936; Seven-Mile Point, no. 11341, July 16, 1936; and Five-Mile Point, no. 11350, July 16, 1936.

Eragrostis pilosa (L.) Beauv. — Waste grounds near Lake Linden, Houghton Co., no. 11570, Sept. 17, 1936. Very far north for this species, at least in Michigan, where it is mostly confined to the southern part of the state.

Poa alpina L. — Copper Harbor, Keweenaw Co., no. 792, Aug. 18, 1890. Not frequent.

Poa palustris L. — Abundant and variable. A coarse plant with large, open, pyramidal panicle having 4–6-flowered purplish spikelets 2–3 lines long. Shores of Torch Lake, Houghton Co., no. 11398, July 24, 1936.

Poa palustris L. var. fertilis (Host.) Asch. and Graebn. — A slender weak plant of shadier places with a contracted panicle and 1–3-flowered green spikelets 1–1.5 lines long. Dollar Bay, Houghton Co., no. 9807, July 1, 1934.

Festuca rubra L. — Rocky woods on Hunter's Point, Keweenaw Co., no. 11270, July 14, 1936.

Festuca saximontana Rydb. — Keweenaw Co.: Hunter's Point, no. 11303, July 14, 1936; West Bluff, no. 11315, July 14, 1936.

Carex gynocrates Wormsk. — In peat bogs. Eagle Harbor, Keweenaw Co., nos. 6630, June 29, 1923, and 11330, July 14, 1936.

Carex praegracilis W. Boott. — In a roadside hollow in Eagle Harbor village, Keweenaw Co., no. 11327, July 14, 1936. Discovered here by Mr. F. J. Hermann. Since this is not a typical jack pine plain, it probably is not the station of Professor Fernald.

Carex exilis Dew. var. androgyna Dew. — Spike monoecious. Eagle Harbor, Keweenaw Co., no. 11333, July 14, 1936.

Carex aenea Fern. — Hillsides at Lake Linden, Houghton Co., no. 9688, June 7, 1934.

Carex rugosperma K. K. M. — Bluffs at Cliff Mine, Keweenaw Co., no. 737, July 7, 1890.

Carex tonsa (Fern.) Bickn. — Sand dunes at Five-Mile Point, Keweenaw Co., no. 11343, July 16, 1936.

Carex Garberi Fern. — Rocky shores and crevices at Hunter's Point, Keweenaw Co., no. 11283, July 14, 1936.

Carex Vahlii Schk. — Shores near Agate Harbor, Keweenaw Co., where it was discovered by Mr. F. J. Hermann. No. 11326, July 14, 1936.

Carex aurea Nutt. var. androgyna Olney, at least in part. — The terminal spike is monoecious. Keweenaw Co.: Cliff Mine, no. 636, July 31, 1888; Eagle Harbor, no. 11332, July 14, 1936.

Xyris montana H. Ries. — Muddy shores of Lake Roland, Houghton Co., no. 10253, Aug. 15, 1934. Very scarce.

Juncus bogotensis HBK. — *Gen. et Sp. Pl.*, I : 235. 1815 (*J. effusus* L. var. β L., *Sp. Pl.*, I : 326. 1753). — *J. effusus* L., *l. c.* (var. α), is *J. arcticus* Willd., which must give way to the older name of Linnaeus. The typical form of the species is not found in Michigan.

Juncus bogotensis HBK. var. compactus (Lej. & Court.) O. A. F., *Am. Mid. Nat.*, 10 : 206. 1927 (*J. communis* C. J. Meyer var. *pseudoconglomeratus* O. A. F., *Mich. Acad. Sci., Ann. Rep.*, 6 : 205. 1904). — Frequent throughout Michigan. Keweenaw Co.: Cliff Mine, no. 465a, Aug., 1900; Eagle River, no. 7488, July 21, 1925. Wayne Co.: Detroit (Belle Isle Park), no. 465b, July 10, 1893. Houghton Co.: Hubbell, no. 9939, July 15, 1934; Lake Linden, nos. 8514, July 29, 1927, and 10169, Aug. 7, 1934.

Juncus bogotensis HBK. var. **solutus** (Fern. & Wieg.), n. comb. (*J. effusus* L. var. *solutus* Fern. & Wieg., *Rhodora*, 12 : 90–91. 1910). — The common variety of the species on the Keweenaw Peninsula. Plants with a large open panicle: Houghton Co.: Lake Linden, nos. 10141, Aug. 2, 1934; 10172, 10173, Aug. 7, 1934; 10203, Aug. 9, 1934; Hubbell, no. 9938, July 15, 1934. Plants with a small, condensed, often globular panicle: Houghton Co.: Lake Linden, nos. 10170, 10171, Aug. 7, 1934; shores of Torch Lake, nos. 11468, 11470, Aug. 11, 1936; Gregory Springs, no. 11068, Sept. 3, 1935; Laurium, no. 11370, July 16, 1936.

Juncus bogotensis HBK. var. **Pylaei** (Laharpe), n. comb. (*J. Pylaei* Laharpe, according to Fern. and Wieg., *l. c.* 92). — Occasional in Keweenaw Co.: Cliff Mine, no. 465, Aug. 1886; Long Swamp, no. 10301, Aug. 21, 1934. Belle Isle, Wayne Co., no. 465c, July 10, 1893.

Erythronium americanum Ker. — In this region we have two very conspicuous variations of this species that could readily be differentiated by size of plants and flowers alone. The smaller one, with

green leaves mottled with paler green or dirty white, with mostly entire stigmas, and with *yellow* stamens, is the typical variety of the species; scapes are from 5 to 10 inches high, with a yellow flower 0.75–1.35 inches long. Keweenaw Co.: Cliff Mine, no. 391, June 24, 1886. Houghton Co.: Lake Linden, no. 9608, May 3, 1934; Bootjack, no. 9634, May 27, 1934. Ontonagon Co.: Misery Bay, no. 10716, May 19, 1935. A specimen from Lake Linden, Houghton Co., no. 11161, May 20, 1936, has a three-lobed stigma. The larger variety is one third to one half larger in all its parts; the stigma is usually three-lobed, and the stamens are *red*, the leaves being mottled with brownish purple. It may be known as

Erythronium americanum Ker. var. **rubrum**, var. nov. — Plantis et floris circa $\frac{1}{3}$ - $\frac{1}{2}$ majoribus, antheris rubris, stigmatibus 3-lobatis. Lake Linden and vicinity, Houghton Co., no. 9607, May 3 and June 1, 1934.

Our local manuals say that this species propagates by offshoots or rhizomes from the base of the bulb. I have never seen offshoots except from a first-year bulb. A bulb two or more years old has no such offshoots; bulbs are probably four years old before they produce a flowering scape. Thereafter propagation is by a bulb in the axil of the scale surrounding the solid bulb or corm; the tip of this new axillary bulb is always seeen protruding above the scale of the old bulb at fruiting time and occasionally as early as the close of the flowering period. I have seen as many as five bulbs still adhering one to another, four being old and nonproductive.

Fissipes hirsuta (Mill.) O. A. F. f. **albiflora** (Rand & Redf.), n. comb. (*Cypripedium acaule* Ait. f. *albiflorum* Rand & Redf., *Fl. Mt. Desert Is.*, p. 154. 1894). — Bootjack, Houghton Co., no. 9681, June 4, 1934.

Polygonum Douglasii Greene. — Shores of Lac La Belle, Keweenaw Co., no. 9278, Sept. 1, 1932.

Polygonum achoreum Blake. — Abundant in southeastern Michigan. Old roadbeds. Calumet, Houghton Co., no. 11512, Aug. 14, 1936.

Portulaca neglecta Mack. & Bush. — Prostrate; large leaves up to 1.5 inches long by one half as wide near the top, and flowers with 16 stamens. In gardens at Lake Linden, Houghton Co.,

no. 11454, Aug. 1, 1936. In a previous paper I referred it to *P. oleracea* L. var. *sativa* (Haw.) DC., but this variety is erect and has only 12 stamens.

Sophia multifida Gilib. — In waste places at Cliff Mine, Keweenaw Co., no. 852, July 5, 1885. Rare.

Sophia intermedia Rydb. — Roadsides and waste places. Wayne Co.: Belle Isle, no. 1358½, June 4, 1893; Romulus, no. 6172, June 7, 1922. Frequent.

Sophia pinnata (Walt.) Howell. — Roadsides on Belle Isle, Wayne Co., no. 1667½, June 4, 1900. Rare.

Sophia pinnata (Walt.) Howell var. brachycarpa (Richards) O. A. F. — Roadsides on Belle Isle, Wayne Co., no. 1721, July 2, 1901. Frequent. Vast changes have taken place on Belle Isle since I collected on it, so that I have no means of knowing whether these species are still to be found there. Stations for other plants, including *Habenaria leucophaea*, have been obliterated.

Arabis Holboellii Hornem. — Rocky or gravelly grounds at North American Mine, Keweenaw Co., no. 11361, July 16, 1936.

Cardamine flexuosa With. — This seems to be different from the ordinary run of *C. pennsylvanica;* flowers are larger and fewer and the capsules more widely spreading and farther apart. Shore of Torch Lake, Houghton Co., no. 11253, July 3, 1936.

Ribes rotundifolium Mx. — In the valley of Trap Rock River near Lake Linden, Houghton Co., no. 11188, June 9, 1936. This is farther north and west than heretofore reported for this species. No fruit was formed in 1936, which may have been due to the hot, dry summer.

Geum macrophyllum Willd. — Common throughout the state.

Var. **Rydbergii,** new name (*G. oregonense* Rydb.). — Similar to var. *perincisum,* but the terminal leaflet is orbicular; the latter variety has not been detected in this region. Houghton Co.: shores of Torch Lake, no. 11194, June 11, 1936; Sawmill Creek, no. 11242, July 2, 1936.

Pyrus subvestita (Greene) O. A. F. — A shrub or tree. The larger shrubs may reach a height of 30 feet, with the stems as much as 9 inches in diameter, whereas the trees may grow 65 or 70 feet tall, with the trunk as much as 18 inches in diameter. It flowers and fruits as low as 1.5 feet high. This is the common mountain ash of the Lake Superior district, in which it is everywhere abun-

dant. Throughout the state. Keweenaw Co.: Cliff Mine, no. 261, July 5, 1885; Five-Mile Point, no. 8521, July 31, 1929. Houghton Co.: Lake Linden, nos. 8261, Aug. 15, 1928, 9711, June 13, 1934, 10484, 10489, and 10490, Sept. 6, 1934; Hungarian Falls, nos. 10420, 10420a, and 10421, Aug. 30, 1934, and 10863, June 20, 1935. Wayne Co.: Livonia, no. 8330, May 7, 1929.

Pyrus americana (Marsh.) DC. — Very scarce on the Keweenaw Peninsula. Have collected and seen it but twice. Cliff Mine, Keweenaw Co., no. 189, Aug. 22, 1884; Lake Jerrold, Houghton Co., no. 10270, Aug. 15, 1934.

Crataegus irrasa Sargent. Trap Rock Valley near Lake Linden, Houghton Co., nos. 10620, October 9, 1934, 10692, May 14, 1935, and 10809, 10812, 10815, June 11, 1935. It forms impenetrable thickets. Its location here extends its range far westward, since heretofore it has been reported only from northeastern New York and around Montreal in Quebec.

Hudsonia tomentosa Nutt. var. intermedia Peck. — False heather. The only place I have seen this plant in Michigan is on the yellow sand beach at Bete Grise Bay, Keweenaw Co., where it is associated with beach grass. There is not much of either species or variety. No. 9289, Sept. 1, 1932.

Chimaphila umbellata (L.) Bart. f. americana, O. A. F., *Am. Mid. Nat.*, 12:71. 1930 (Var. *cisatlantica* S. F. Blake, *Rhodora*, 19:241. 1917). — Of the numbers listed under this *forma* at the place cited only nos. 4736 and 6833 belong to it; the other numbers cited belong to the following variety.

Chimaphila umbellata (L.) Bart. var. occidentalis (Rydb.) S. F. Blake, *l. c.*, p. 242. — Very abundant on the Keweenaw Peninsula. Blake places my no. 343 in his variety *cisatlantica*, with the footnote: "These specimens are remarkable for their ovate acuminate sepals." Since my specimens of this number have typical *occidentalis* calyx lobes, I think there may have been some confusion with Nichols no. 861 from Cape Breton and that therefore this footnote as it refers to my number should be deleted and the Keweenaw plant transferred to var. *occidentalis*. Keweenaw Co.: Eagle River, no. 343b, July 3, 1915; Eagle Harbor, no. 11151, May 15, 1936; Copper Harbor, nos. 343a, Oct. 17, 1914, 343c, July 8, 1915, 8503, July 24, 1929, and 10943, July 25, 1935; Hunter's Point, no. 11309, July 14, 1936. Houghton Co.: Lake

Linden, nos. 9911, July 11, 1934, 10641, Oct. 14, 1934, and 11424, July 27, 1936. The leaves are quite variable, often on the same plant, passing from linear (2 by 8 lines) through narrowly to broadly oblanceolate and broadly obovate (10–14 × 20–25 lines). The longest are narrowly oblanceolate and about 3.75 inches long.

Gaultheria procumbens L. f. suborbiculata Fern. — On sand dunes at Five-Mile Point, Keweenaw Co., no. 11347, July 16, 1936. Rare.

Primula intercedens Fern. — Rocky shores of Lake Superior. Keweenaw Co.: Porter's Island, no. 1614, Aug. 22, 1898; Hunter's Point, no. 11281, July 14, 1936; Eagle Harbor, no. 9473½, Aug. 11, 1933. Infrequent.

Gentiana flavida A. Gr. — Rare on the Keweenaw Peninsula. I find that the anthers, united in a ring, separate when the pollen has been shed. Humboldt, Keweenaw Co., no. 10319, Aug. 21, 1934. Have also collected it in Oakland Co.: Bloomfield, nos. 4606, Sept. 16, 1917, 5111 and 5112, Sept. 8, 1918, with leaves in three. Washtenaw Co.: Superior, no. 7688, Oct. 14, 1925, and Pittsfield, no. 7831, Sept. 29, 1926.

Mertensia paniculata (Ait.) G. Don. — Occasional in alder thickets. Keweenaw Co.: Phoenix, no. 282, July 26, 1885; shores of Montreal River, near Mount Houghton, no. 282a, June 30, 1895. Houghton Co.: Trap Rock Valley, near Lake Linden, no. 10820, June 13, 1935.

Mertensia paniculata (Ait.) G. Don. var. longisepala Macbride. — Trap Rock Valley, Houghton Co., no. 11189, June 9, 1936.

Myosotis laxa Lehm. — Shores of Torch Lake, Houghton Co., no. 11254, July 3, 1936; Parkedale Farm, Oakland Co., no. 6945, July 2, 1924.

Myosotis scorpioides L. — Escaped and established on Belle Isle, Wayne Co., no. 2627, June 6, 1912.

Verbena bracteata Lag. & Rodr. — A prostrate herb along roadsides and in waste places. Houghton Co.: Hubbell, no. 9932, July 15, 1934; Calumet, no. 11513, Aug. 14, 1936. Wayne Co.: Conner's Creek, Detroit, no. 2875, July 18, 1912. The Keweenaw stations extend the range of this species much farther north than it is generally recorded.

Agastache Foeniculum (Ph.) OK. — Fragrant giant hyssop; anise hyssop. Found on the prairie near Lake Roland, Houghton Co.,

no. 10232, Aug. 15, 1934. This is farther east than heretofore recorded for this species.

Mentha canadensis L. var. lanata (Piper) Piper. — Wild mint. The flowers are blue, and the stems and petioles are long-pilose or lanate. In the typical species the flowers are white, and the plant is less pubescent. Swamps and shores. Houghton Co.: Gregory Springs, no. 10918, July 23, 1935; Hungarian Falls, no. 11089, Sept. 7, 1935; shores of Torch Lake, no. 11426, July 29, 1936.

Solanum rostratum Dun. — Bull nettle; buffalo bur. In the spring of 1934 one large plant was seen which had survived the winter; it had an abundance of seed, but since no new plants have been found, the seed were probably winter-killed. Gregoryville, Houghton Co., no. 9601, May 1, 1934.

Utricularia resupinata B. D. Greene. — Sandy shores of Lakes Roland and Jerrold, Houghton Co., nos. 10248 and 10271, Aug. 15, 1934. A rare and delicate species. Associated with *Xyris montana* and *Eriocaulon aquaticum.*

Plantago indica L. (*P. arenaria* W. & K.). — A native of Siberia and of south and middle Europe. It is a very frequent plant along the tracks of the Michigan Central Railroad in Wayne Co. It is called fleawort and sand plantain. The seeds are used in medicine. Wayne Co.: Inkster, no. 8979, Aug. 11, 1931; Sheldon, nos. 8947, July 21, and 9011, Oct. 6, 1931; Dearborn, no. 8989, Aug. 11, 1931. Houghton Co.: Lake Linden, nos. 9231, Aug. 27, 1932, 10448, Sept. 1, and 10648, Oct. 20, 1934.

Lonicera Douglasii DC., in large part (*L. glaucescens* Rydb.; see *Am. Mid. Nat.*, 11:267. 1929). — In the Lower Peninsula of Michigan the plants are climbers, creeping over low shrubs. On the Keweenaw Peninsula they never climb, nor do the stems, though curved, twist about each other. There is a difference in the color and size of the flowers. It is possible that they are two distinct species. Additional numbers for Keweenaw Co. are as follows: Mt. Brockway, no. 9749, June 20, 1934; Eagle Harbor, no. 9746, June 20, 1934; Delaware, no. 10945, July 25, 1935; Hunter's Point, no. 11304, July 14, 1936. The variety with glandular fruit may be known as

Lonicera Douglasii DC. var. **dasygyna** (Rehder), n. comb. (*L. glaucescens* Rydb. v. *dasygyna* Rehder).

Lonicera villosa (Mx.) R. & S. var. Solonis (Eaton) Fern. — Asso-

ciated with *L. oblongifolia* (Goldie) Hook. in bogs and swamps, where it is abundant in the western part of Keweenaw Co.: Cliff Mine, no. 60, Aug. 20, 1883; Long Swamp, no. 11351, July 16, 1936.

Lonicera prolifera (Kirch.) Rehder. — A high climber over shrubs. Rare on the Keweenaw Peninsula. Extends the range farther north than heretofore recorded except for the lone instance of Beal in his *Michigan Flora*, where my early collection is on record. Cliff Mine, Keweenaw Co., no. 858, July 5, 1895; Trap Rock Valley, Houghton Co., no. 10892, July 9, 1935.

Boltonia asteroides (L.) L'Hér. — Quite abundant along the shores of Detroit River. Brownstown Township, Wayne Co., no. 8736, Aug. 26, 1930. Rays varying from purplish to white.

Adenocaulon bicolor Hook. — Beal gives but one station for Michigan — Ontonagon River. It is rather frequent on the Keweenaw Peninsula, in moist, rich, cold woods generally of the mixed type. In woods east of Lake Fanny Hooe, Keweenaw Co., no. 2199, Oct. 7, 1910; Lake Linden, Houghton Co., where abundant, no. 9788, June 28, 1934.

Helianthus Maximiliani Schrad. — Frequent on dry banks. Hungarian Falls, Houghton Co., no. 11095, Sept. 7, 1935. Does not appear to be an introduction. The dwarfed form with reduced inflorescence and root system, var. *Dalyi* (Britt.) O. A. F., was found near by, no. 11094, Sept. 7, 1935.

Quizotia abyssinica (L. f.) Cass. — Niger seed; til seed. This plant is a native of Africa, where it is cultivated for its oil. The seed is frequently in the mixture sold for food for canaries. Mr. Blake says that it is the first time he has heard of its escape in this country. Its general appearance is very much like that of some species of Bidens, which I at first thought it was. Banks of the River Rouge, Wayne Co., no. 8786, Sept. 23, 1930.

Achillea subalpina Greene. — Rocky shores of Lake Superior at Hunter's Point, Keweenaw Co., no. 11294, July 14, 1936.

Matricaria Chamomilla L. — German chamomile. Along railways at Lake Linden, Houghton Co., no. 10167, Aug. 6, 1934.

Arnica Whitneyi Fernald. — The publication of our Keweenaw arnica as a new species by Mr. Fernald has revived interest in a plant long ago collected and later forgotten, since it was not considered to be anything new and had already been reported. At

that time it was generally called *A. mollis* Hook. It was found at Eagle Harbor, Keweenaw Co., by Mr. F. E. Wood, under whom I first studied botany in school at Cliff Mine in 1882–83. Mr. Wood found it in 1884 and reported it as covering an entire side of a hill and making a wonderfully beautiful picture. He sent specimens to the University of Michigan; but since they are not there now they probably were destroyed in the fire of 1913. I have one of his specimens of that collection. I also found it the same year near Copper Harbor, no. 250, July 15, 1884. This was in a deciduous woods near the old cemetery under Mt. Brockway west of Copper Harbor. Mr. F. J. Hermann found it in mixed woods on conglomerate ground near Fort Wilkins, a mile east of Copper Harbor, where I collected it later; no. 11268, July 14, 1936.

Lake Linden, Houghton County
Michigan

ADDITIONS TO THE FLORA OF MICHIGAN

CLARENCE R. HANES

THE plants reported in this paper are chiefly discoveries made in 1936. Some previous additions to the flora of Michigan are given in Mr. F. J. Hermann's "Notes on the Flora of Michigan," *Rhodora*, 38 (1936) : 362–367. All species here cited were found growing in Kalamazoo County. The credit for finding one belongs to Mr. H. R. Becker of Climax and for another to Mr. Fred Rapp of Vicksburg. The remainder are the collections of Mrs. Florence Hanes and the writer.

The grasses have been checked by Mrs. Agnes Chase, of the United States Bureau of Plant Industry; the other species represented have been either checked or determined by Dr. J. H. Ehlers or Mr. F. J. Hermann, of the University of Michigan. The University Herbarium has duplicates of all except *Stipa comata*.

Most of the new discoveries were made along railways and through highways. Here we may expect to meet with plants brought in from foreign countries or from other parts of the United States in stock litter or feed or in materials used for packing. If such plants find the soil conditions congenial and are able to withstand the climate and the burning and mowing of the section men, they may become established far from their usual range. The Grand Trunk Western Railroad has been the most prolific source for new material. A few of the species discussed are considered indigenous to the state, although not reported prior to the present paper.

With several exceptions the species here mentioned are, so far as could be discovered, for the first time reported as growing in Michigan. The exceptions are plants that have only rarely been found in the state. Any new localities that can be given for them should be considered an addition to the knowledge of the flora of our state.

List of Species

Stipa comata Trin. & Rupr. — In sandy soil along the Grand Trunk Railway, Brady Township, northeast of Vicksburg, Sept. 26, 1936.

Not over a dozen clumps of this grass were found. The growth showing in late September was very stiff and wiry. A few of the old culms were gathered, and later observation fortunately revealed one lone awn, which, together with the fact that the base of the still persistent panicle was included in the sheath, made the determination possible.

TRIODIA FLAVA (L.) Smyth. (*Tridens flavus* (L.) Hitchc.). — Along the Kalamazoo–Detroit highway east of Kalamazoo, Sept. 3 and Sept. 22, 1936.

Mrs. Chase has no record of this species from Michigan. Dr. Ehlers, however, states that it is represented in the University Herbarium by a specimen collected in 1838 by the first Geological Survey. According to Dr. W. J. Beal,[1] it was collected in the southeastern part of the state and is included in John Wright's *Catalogue of the Phaenogams and Filicoid Plants Collected on the Geology Survey of Michigan*.[2] It is also given in Herbert's list for Berrien Co.[3]

POA PALUDIGENA Fern. & Wieg. — Brady Township, north of Portage Lake, May 26, 1936; southwestern part of Prairie Ronde Township, May 29, 1936.

Growing in wet birch-tamarack swamps in small tufts, often in moss. Mr. H. R. Becker's determinations for the mosses found with the roots of the collected specimens of *P. paludigena* are *Amblystegium riparium* and *Elodium paludosum* (*Thuidium paludosum*), both species of very wet localities.

Hitchcock's *Manual* reports that it is found in only six states, of which Michigan is one. Mrs. Chase gave the Michigan collections as follows: Dodge, 34, in 1904 near Port Huron; Wheeler in 1880 at Hubbardston; Beal in 1898 at Muskegon. No report of a recent collection of this species in Michigan was given.

CAREX STRAMINEA Willd. (not *C. straminea* of *Gray's Manual*, Seventh Edition). — Sandy soil near border of blueberry swamp, Schoolcraft Township, northeast of Sugarloaf Lake, July 3, 1934.

CAREX AGGREGATA Mack. — Schoolcraft Village, June 6, 1936.

This sedge has been growing for the past three years, at least,

[1] *Michigan Flora*, p. 47. 1904. It is here listed as *Tricuspis seslerioides* (Mich.) Torr.

[2] This catalogue was published as a legislative report in 1839.

[3] Herbert, P. E., "Ferns and Flowering Plants of Berrien County, Michigan," *Am. Mid. Nat.*, 15: 325. 1934.

on a lawn near a wood where carices are plentiful. It may be a native or an import in lawn mixtures.

CABOMBA CAROLINIANA Gray. — Kimble Lake, Schoolcraft Township, Aug. 21, 1936, Fred Rapp.

The discovery of *Cabomba* by Mr. Rapp is the outstanding addition to the flora of the state. Previously the northern limit for this species has been given as southern Illinois. Kimble Lake lies in the southeastern corner of Schoolcraft Township. It is the type of lake that was not greatly affected by the drought of 1936. Mrs. Hanes and the writer found *Cabomba* abundant here on August 21, 1936. It was growing in about six feet of water. Some of the plants were only a foot or two high and looked like miniature pine trees; others were in blossom a foot or so below the surface of the water and a few had reached the surface.

Parts of plants, no doubt dislodged by fishermen, were floating near the shores of the lake. Many of these were sending out rootlets along the stem. This propensity of *Cabomba* later gave the idea that Kimble Lake might not be the only location for this plant. On October 31, 1936, floating specimens were found in the outlet one-half mile from the lake. On November 13, 1936, Portage Creek, the inlet to Kimble Lake, was explored, and numerous plants of this species were found growing at least one-half mile distant by water from the lake. It is quite possible, therefore, that *Cabomba* grows in Barton Lake in Schoolcraft Township and in Portage Lake, in St. Joseph County, both of which are connected with Kimble Lake.

MEDICAGO FALCATA L. — Prairie Ronde Township, along the Grand Trunk Railway, one and one-half miles west of Schoolcraft, July 12, 1936.

CROTALARIA SAGITTALIS (Dill.) L. — One mile east of Schoolcraft, Schoolcraft Township, Aug. 3, 1936.

A small colony of this species is growing along the Grand Trunk Railway east of Schoolcraft. The roadbed has been built up where the tracks cross a marsh, and on the sandy slope so made plants in flower and in seed were thriving. *Michigan Flora* gives O. A. Farwell credit for finding it in Detroit.[4]

TRIBULUS TERRESTRIS L. — Schoolcraft Township, two miles east of Schoolcraft on Grand Trunk Railway, Sept. 7, 1936

[4] Beal, *op. cit.*, p. 91.

The colony of this species comprised about twenty plants. A later visit revealed many young plants just started, which shows that they were probably "winter" annuals.

EUPHORBIA DENTATA Michx. — Grand Trunk Railway in the village limits of Schoolcraft, Aug. 20, 1936.

This spurge was reported by Walpole[5] as rare in Washtenaw County. In Kalamazoo County it has been seen only along our railways. Here it is frequent or abundant along the Michigan Central and along the Grand Trunk and the branch of the New York Central lines running through Schoolcraft. It has been found intermittently for at least twenty miles on the Grand Trunk right-of-way. Unlike some of the other introductions, that are represented by a single colony, this species is well scattered in much of the county.

VIOLA TRILOBA Schwein. — Schoolcraft Township, south of the village of Vicksburg, May 19, 1936; Portage Township, near the southeastern part of Austin Lake, June 15, 1936.

The plants were found in both locations on land thinly forested with oak. In the first they were growing quite close to the edge of a tamarack swamp. Mr. Fred Rapp had found these violets near Vicksburg previous to 1936, but had not made any written report of them.

PHLOX BIFIDA Beck. — Schoolcraft Township, along branch of the New York Central lines one and two miles south of Schoolcraft, July 26, 1936.

A species rare in Michigan, according to Beal.

LINDERNIA ANAGALLIDEA (Michx.) Pennell (*Ilysanthes anagallidea* (Michx.) Robinson). — Schoolcraft Township, east of Gourdneck Lake, Aug. 15, 1936.

A specimen sent to Dr. Pennell was reported as the first record for Michigan. The swamp where this species grew is usually under water. In 1934 it was completely burned over and left a blackened waste for the remainder of that year. During 1935 there was a luxuriant growth of *Viola lanceolata*, *Rotala ramosior*, and *Ludvigia polycarpa*, with half of the swamp covered with water. The drought during August of 1936 again made this swamp entirely dry, and it was near where it is usually the wettest that the Lindernia grew. The plants seed abundantly.

[5] Walpole, B. A., *Flora of Washtenaw County*, p. 52. 1924.

PLANTAGO ARENARIA W. & K. — Along the Kalamazoo–Detroit highway east of Kalamazoo, Sept. 3, 1936.

This species is not recorded in *Gray's Manual*, Seventh Edition . Only one location for the United States is given in the first edition of Britton and Brown's *Illustrated Flora;* two are listed in the second edition.

PARTHENIUM HISPIDUM Raf. (*P. repens* Eggert). — One and one-half miles west of Schoolcraft, Prairie Ronde Township, along Grand Trunk Railway, July 11, 1936.

The range of this species is given as Missouri–Kansas to Texas. The colony of these plants growing in Michigan must have found a congenial climate and favorable soil conditions, since it now occupies a triangular space of thirty by twenty feet, with several hundred plants crowded closely together.

LEPACHYS COLUMNIFERA (Nutt.) MacB. (*L. columnaris* (Sims) T. & G.). — Camp Custer, July 10, 1936, H. R. Becker.

Probably brought to the camp in hay from the West.

THELESPERMA TRIFIDUM (Poir.) Britton. — Along the Grand Trunk Railway, four miles west of Schoolcraft in Prairie Ronde Township, July 18, 1936.

This species has nearly the same natural range as *Parthenium hispidum.* It is more scattered in growth and occupies a larger space of ground. Apparently it has become well established.

CENTAUREA PICRIS Pall. — Prairie Ronde Township, along the Grand Trunk Railway, one-half mile west of Schoolcraft, Aug. 29, 1936.

Probably adventive from the West, where it was introduced from Asia with alfalfa seed and is locally common.[6] Minnesota and Missouri are apparently the easternmost states from which it has previously been reported.

CREPIS CAPILLARIS (L.) Wallr. — On a farmyard lawn in Prairie Ronde Township, July 24, 1936.

Dr. Ehlers reports that the only Michigan specimens in the University Herbarium are from Antrim County.

SCHOOLCRAFT, MICHIGAN

[6] Blake, S. F., "Two New Western Weeds," *Science,* 55 : 1426. 1922

A LOW LIGHT INTENSITY PHOTOELECTRIC DEVICE FOR THE MEASUREMENT OF LEAF AREAS

RUFUS P. HIBBARD, BUFORD H. GRIGSBY, AND WILLIAM G. KECK

THREE years ago during the course of some physiological studies on red raspberry plants affected by the virus disease known as red raspberry mosaic, it was desired to determine the area of a large number of leaves on several successive days. The nature of the studies made it imperative to find a rapid means of area measurement.

Although a light sensitive cell has been available for some time for this purpose, Gerdel and Salter (2) appear to have made the first application of a photoelectric device to the measurement of leaf area. The device reported by these investigators employed as a light source a balopticon operated from 110-volt current. The light from it was projected upon the leaf, and the amount of light shut out by the leaf tissue was detected by a light sensitive cell. Because of the type of current used a light of rather high intensity was produced. Leaf tissue is not entirely opaque, and a certain amount of such a light would be transmitted by the leaf and result in a considerable error in the area observed. This device has a further disadvantage in that it is serviceable only in a completely darkened room, which makes it of rather limited usefulness.

Frear (1) reported on a somewhat simplified apparatus in which he used as a light source five 60-watt bulbs suspended above a photoelectric cell. To secure diffusion of the light a frosted glass plate and a baffle were inserted between the leaf and the photoelectric cell. The intensity of the light falling on the leaves was high, and here again no calculation of a transmission factor was made.

In a device described by Withrow (4) an attempt was made to eliminate the error brought about by transmission of light. In it

twenty bulbs, of which twelve were of 100-watt capacity and eight of 60, were used as a light source. Uniform distribution of light was secured by inserting a Florentine glass immediately below the bulbs and by the use of a diaphragm below the leaves. The current consumption of this device is approximately 1,700 watts and, therefore, leads to the production of a very high light intensity inside the apparatus. Considerable heat is also liberated, which decreases the accuracy of the calibration curve and is an undesirable factor when attached leaves are to be measured. In an effort to avoid the error brought about by the transmission of light Withrow calculated transmission factors for a number of types of leaves. He assumes that the application of such factors will compensate for the errors involved, but this would necessitate a new set of factors for each type of leaf to be measured and, consequently, increase the time necessary to make a set of area measurements.

The leaves of raspberry plants affected with mosaic have a characteristic mottled appearance, brought about by the formation of irregular patches of tissue with different shades of green and yellow. These irregular areas also vary considerably in thickness. With leaves showing this lack of uniformity it was found to be impossible to calculate satisfactory transmission factors. The physiological studies on these mosaic-infected raspberry plants extended over a considerable period and, consequently, leaves in various stages of development were used. The relative age of the leaf has a marked influence upon the thickness and the color; and, therefore, a new set of transmission factors would need to be determined to prevent error in area measurements due to age differences.

The instrument to be described in this paper was designed to eliminate the necessity for calculation of transmission factors of any sort. It was assembled in the summer of 1934 and has been in continuous use in a number of physiological studies on raspberry plants.

It was thought that a light of low intensity would prevent the transmission of light by the leaf tissue. The proper intensity of light was secured by substituting a 6-volt storage battery for the 110-volt current used in other devices by previous investigators. Uniform distribution was obtained by using a number of low-voltage bulbs and a ground-glass diffusion plate. Figure 1, Plate I, is a photograph of the apparatus as set up for operation.

The illuminator consists of twenty-one flashlight bulbs, of 3.8 volts

each, set in receptacles, which in turn are mounted on a light-weight circular wood base 12 inches in diameter. The receptacles may be arranged in any convenient pattern, but when the electrical connections are made the bulbs should be divided into equal groups. All the members of a group are wired in series and then the groups are connected in parallel. This parallel arrangement in series insures uniform intensity of light over the entire area of the diffusing plate.

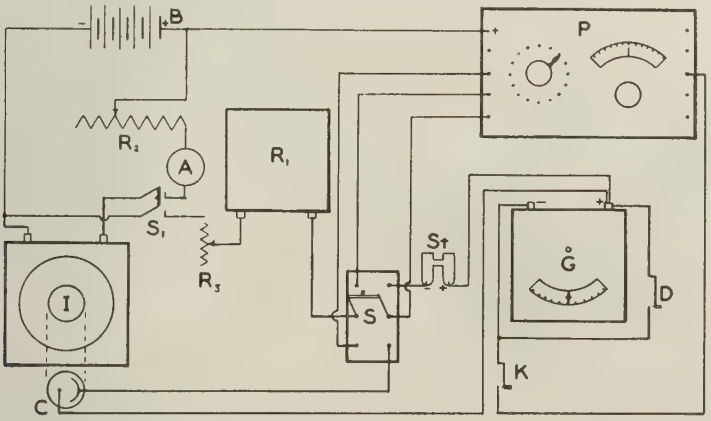

FIG. 1. Diagram of wiring of apparatus for measurement of leaf areas

KEY TO ABBREVIATIONS

B — six-volt battery	St — standard cell
R_1 — resistance box	I — illuminator
R_2 — slide-wire rheostat	P — potentiometer
R_3 — variable resistance	G — galvanometer
A — D. C. ammeter	K — key switch
S — double-throw knife switch	D — damping switch
S_1 — knife switch	C — photoelectric cell

This base is placed at the bottom of a hexagonal box 4 inches deep whose sides are 5 inches long. A cover having a circular opening 7 inches in diameter is provided for the box. Two ground-glass plates are fitted into this opening, and a layer of felt is cemented to the cover around the opening. The felt is provided in order to prevent injury to the leaf petioles.

A cone of polished tin, 12 inches high, 8 inches in diameter at the base, and 2 inches in diameter at the apex, is placed over the glass plates. At the apex of the cone is a wood cup turned to fit a

Weston photronic cell. This arrangement of box and cone was designed for raspberry leaves, but slight modification of structure would make it applicable to other leaves. Figure 2, Plate I, is a photograph of the illuminator and the cone.

The photronic cell is connected to a Leeds and Northrup Student type potentiometer with a Weston, Model 4, galvanometer in the circuit between the cell and the potentiometer. A standard cell and a resistance box are provided to adjust the current passing through the potentiometer. Details of the wiring are shown in Figure 1.

When the apparatus is in operation the current passing through the bulbs of the illuminator is kept at 5 amperes. It was found that this amount of current passing through twenty-one bulbs, though not strong enough to bring the bulbs up to full brilliancy, was still sufficient to give uniform illumination at the surface of the ground-glass plates.

The amount of light transmitted by leaf tissue was determined by using known areas of leaf tissue of different ages and of varying degrees of mottling. A circular piece of heavy black paper was placed over the glass plates in such a way that all the light was shut off from the photronic cell. A potentiometer reading was taken, and it was found that an extremely low value was obtained. Then a square opening of 25 square centimeters was cut in the paper. Leaf tissue was placed over this opening in such a way that it was completely covered. Potentiometer readings were taken again, and in every case the reading was the same as that given when the area was entirely dark. One would expect to find a zero reading when the light from the bulbs was shut out, but at the time when these determinations were made the instrument had only a single layer of felt surrounding the glass plates, and a small amount of light coming from outside the instrument was able to enter at the base of the cone. The photronic cell used is very sensitive, and the small amount of light produced the low reading. Another layer of felt has since been added, and true zero readings are obtained when the bulbs are shut out. No doubt green light is transmitted, and there is also a probability that the percentage of transmission is proportional to the intensity of the source of light, but, as experimental evidence shows, it is evident that in the range of intensity used the percentage of transmission is not sufficient to necessitate the calculation of a transmission factor. The photronic cell, though sensi-

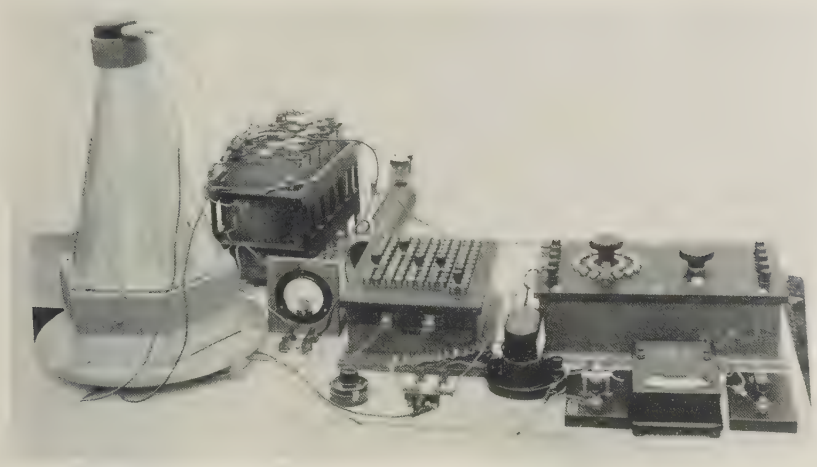

FIG. 1. The entire photoelectric device for measuring leaf area, as set up for operation

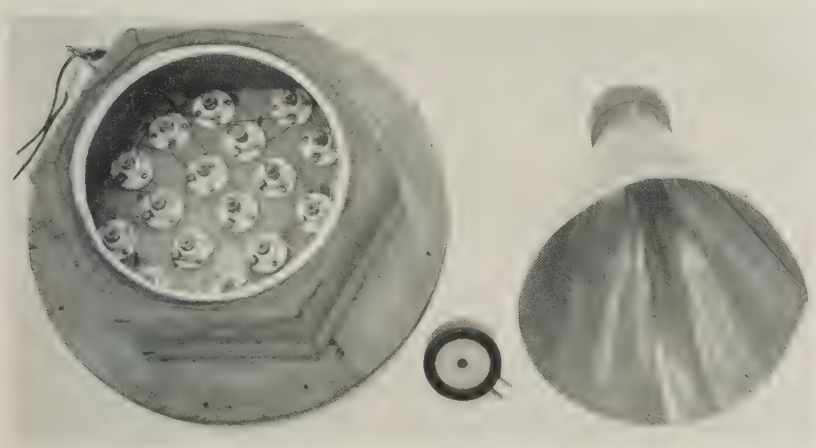

FIG. 2. The illuminator, photronic cell, and cone

tive to green light at high intensities, is not sensitive at low ones. Also the light from the tungsten filaments is of a low order of productivity in the green or wave length of 520–555.

The instrument was calibrated by measuring the voltage produced by the photoelectric cell when metal disks of known area were inserted between the ground-glass plates. With the cone and the cell in place over the glass plates, the current was turned on and the instruments were allowed to reach equilibrium. A reading of the potentiometer at zero deflection of the galvanometer was then

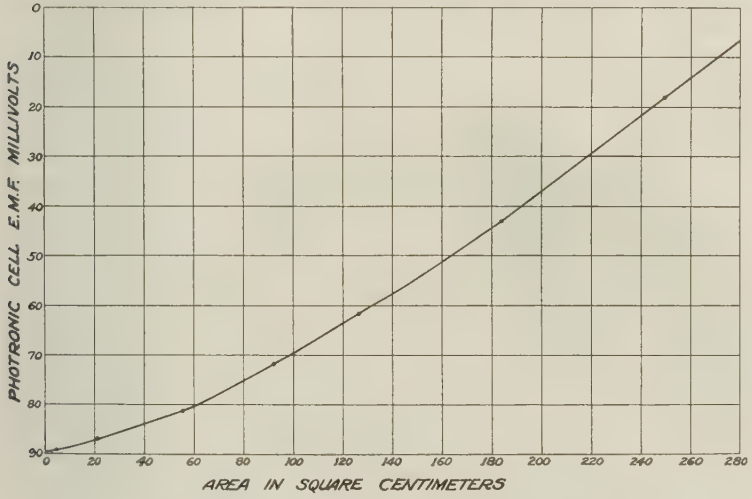

Fig. 2. Calibration curve of the photronic cell

taken. Disks ranging from 1 to 7 inches in diameter were inserted between the glass plates, and the reading of the potentiometer at zero deflection of the galvanometer was observed in each case. The difference in voltage produced by the cell caused by the blocking out of that area was then obtained by subtraction from the original reading. These values plotted against the area selected give a curve which can be employed in determining unknown areas. The curve obtained in this manner is illustrated in Figure 2.

Withrow (4) has shown that a straight-line type of curve can be obtained by shunting a suitable resistance across the photronic cell, but this lowers the sensitivity of the cell. Since this apparatus is

operated with a very low light intensity, it was thought that more accurate readings would be secured by retaining the full sensitivity of the cell rather than by having a straight-line calibration curve.

After the calibration curve has been established the determination of the area of a leaf is a simple matter. The leaf to be measured is inserted between the ground-glass plates in order to keep the leaf margin from rolling. The cone is then set over the plates, the potentiometer adjusted to zero deflection of the galvanometer, and the voltage observed. By subtracting this voltage from that noted before the leaf was inserted the change produced by the leaf tissue can be found.

This value when located on the curve indicates the area of the leaf measured. The time necessary to make an area determination is very short. With the apparatus at equilibrium it may be less than one minute, depending, of course, upon the skill of the operator and his degree of familiarity with the instrument.

The cost of an instrument of this sort is not great, and it does have some advantages which other photoelectric devices reported before this do not have. A 6-volt current produces light of the desired intensity, and together with many bulbs of low voltage a uniformity of light distribution is obtained without any need of a complicated system of lenses, baffle plates, etc. The elimination of transmission factors saves considerable time in calculations and also renders the photoelectric method applicable to studies of leaves which are mottled, variegated, or otherwise not uniform in thickness or color. The device is especially valuable in the measurement of the area of compound leaves. Furthermore, the adaptability of a storage battery makes the apparatus portable and thus greatly extends its usefulness. If the various parts are mounted on a suitable frame, the instrument can be carried to any point where plants may be growing and the area of one leaf or the entire leaf system of a plant determined without unduly disturbing the plant. Many of the separate parts, such as galvanometer, standard cell, etc., can be obtained in one compact instrument, an advantage which makes the entire apparatus smaller and more readily transportable.

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Note — The paper by Kramer (3) came to our attention too late to be included in the discussion. — Authors.

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NOTES ON NEW OR UNUSUAL MICHIGAN DISCOMYCETES. V *

BESSIE B. KANOUSE

THIS paper is a continuation of reports on a survey of the discomycetes of Michigan.[1] Thirteen additional records are given here. Included are one new genus and species, *Acervus aurantiacus*, sp. nov., one new variety, *Lachnea stercorea* Gill. var. *microspora*, var. nov., and one new combination, *Dasyscyphella miniopsis* (Ellis) Kanouse. The collections are deposited in the Herbarium of the University of Michigan.

List of Species

Acervus aurantiacus, sp. nov.[2] (Fig. 1). — Apothecia sessile, densely caespitose in clusters varying from a few to many, much contorted from mutual pressure, attachment centric to subcentric, arising from a black, tough, rubbery sclerotiform base composed of thin-walled mycelia intermingled with débris, reaching a diameter of 4 cm., externally slightly verrucose, soft-leathery and pliant when fresh, somewhat friable when dry, "capucine orange"[3]

* Papers from the Herbarium of the University of Michigan.

[1] See Kanouse, B. B., "Notes on New or Unusual Michigan Discomycetes," *Pap. Mich. Acad. Sci., Arts, and Letters*, 19 (1933) : 93–106; 20 (1934) : 65–78; 21 (1935) : 97–104; 22 (1936) : 117–122.

[2] **Acervus,** gen. nov. — Apotheciis caespitosis, sessilibus, vel substipitatis in sclerotiformibus radicibus, coriaceis, fixis centralibus vel subcentricis, coloratis; hypotheciis parenchymaticis; excipulis prosenchymaticis; sporis ellipsoideis, nonseptatis, hyalinis; paraphysibus crassis, irregulariter auctis, coloratis. Species typica *Acervus aurantiacus*.

Acervus aurantiacus, sp. nov. — Apotheciis caespitosis, sessilibus in nigris sclerotiformibus radicibus, coriaceis, 4 cm. crassis, aurantiacis; hypotheciis parenchymaticis; excipulis prosenchymaticis; ascis cylindraceis, 100–140 × 7–10 μ, J−, 8-sporis; sporis ellipsoideis, 6–8 × 3.5−4 μ, 1-guttulatis, nonseptatis, hyalinis; paraphysibus clavatis vel irregulariter auctis, 9 μ crassis, aurantiacis.

Specimen typicum in terra prope South Lyons, Michigan, A. H. Smith, 5044, in Herb. Univ. Mich. conservatum.

[3] The colors cited in quotation marks are those of R. Ridgway, *Color Standards and Color Nomenclature*, 1912.

to "salmon-orange," hymenium "capucine orange" becoming "chestnut" to "Sudan-brown" when dry, even, hypothecium up to 400 μ thick, parenchymatic, cells very large, thin-walled, loosely arranged forming a somewhat spongy layer, cells filled with an orange-colored substance which is soluble in water, exciple less than 100 μ thick, prosenchymatic, loosely woven hyphae extending to the surface in clusters forming minute pili, tinted yellow; asci cylindric, thin-walled, in mature asci the basal part collapses and the apical portion frequently becomes distended, dehiscence by means of a rupture of the ascus wall, not bluing with iodine, 100–140 × 7–9 (10) μ, 8-spored; spores smooth, one-celled, uniseriate in young asci, frequently becoming

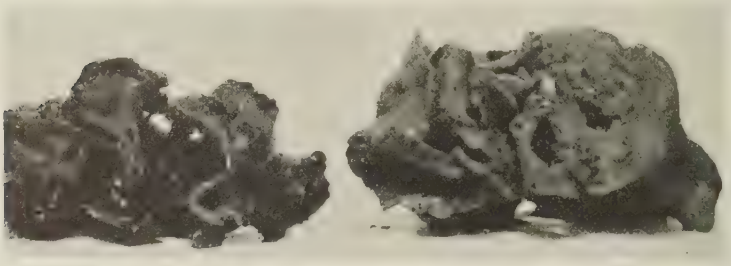

FIG. 1. *Acervus aurantiacus*, sp. nov., × 1 (photograph by A. H. Smith)

crowded irregularly in the tips of older asci, uniguttulate, hyaline, ellipsoid, 6–8 × 3.5–4 μ; paraphyses cylindric, stout, peg-shaped, tapering upward from broad basal attachments, frequently variously and irregularly enlarged, slightly longer than the asci, contents homogeneous, colored orange, up to 9 μ in diameter.

On soil around roots of an elm tree in a bog, South Lyons, Michigan, October 6, 1936. Type collected by Alexander H. Smith (S. 5044).[4] Type deposited in the Herbarium of the University of Michigan.

The characters of unusual interest are the sclerotiform base, the stout paraphyses, the absence of an operculum and the presence of a bright orange, water-soluble substance in the paraphyses and in the hypothecium. Sections made from fresh material or

[4] The letters "M.," "S.," and "K." accompanying the collection numbers indicate the collectors E. B. Mains, A. H. Smith, and B. B. Kanouse, respectively.

from dry apothecia revived in water showed a peculiar characteristic of the asci. The upper portion frequently became expanded into subglobose or cylindric heads, into which a part of the spores became crowded. No operculum or specialized pore was found. The rupture was usually apical, although sometimes it was slightly below the tip of the ascus. When apical it involved the entire end of the ascus, and the edges sometimes flared outward giving the effect of an urn. The lower parts of the asci were completely collapsed, and the upper parts that contained the spores frequently were broken away. Many of the heads and chainlike lengths of spores consisting of from 3 to 6 spores were seen floating free in the mounting medium, held in position by an almost imperceptible fragment of the ascus wall.

The paraphyses are the conspicuous feature of the hymenial layer. They are stout and peglike and project slightly beyond the asci, but do not form a true epithecium. Their contents are homogeneous and orange-colored.

This fungus was studied most satisfactorily when the sections were mounted in concentrated ammonia, which prevented the dissolution of the coloring matter and expanded and separated the hymenial structures so that they could be examined. When sections were mounted in water or in media containing acids the asci and paraphyses adhered closely, and the color was released so that it was practically impossible to study them.

The size and the color of the apothecia resemble those of *Aleuria aurantia* (Müller) Fuck., but the similarity is merely superficial. The plant does not belong to the operculates. The leathery texture, the type of asci with the small spores, the absence of an operculum, the structure of the apothecia, and the presence of a sclerotiform base suggest affinities with fungi in the Dermataceae, in which family it is here placed.

Ascophanus glaucellus Rehm. — On dung, Marquette, Sept. 8, 1934, E. B. Mains (M. 34–111).

Clithris crispa (Pers.) Rehm. — On stems of *Vaccinium sp.*, George Reserve, University of Michigan, Pinckney, May 7, 1933, A. H. Smith (S. 33–68).

Dasyscyphella miniopsis (Ellis) Kanouse, comb. nov. — On bark of *Acer saccharinum*, George Reserve, University of Michigan, Pinckney, May 13, 1933, A. H. Smith (S. 33–34). Since the de-

scription given by Ellis is rather brief an account of our material is added here.

Apothecia solitary to gregarious, sessile, less than 1 mm. broad, narrowed at the base, white to pale orange-buff externally, hairs conspicuous at the margin, hyaline to pale yellowish, aseptate, glistening, more numerous at the margin, twisted spirally; disk pale rose to white, drying pale orange, asci conspicuously clavate-cylindric, 100–130 × 10–12 μ, not bluing with iodine, 8-spored, few in an apothecium; spores filiform, many-septate, hyaline, 50–75 × 3–3.5 μ; paraphyses filiform, branched, hyaline.

A fungus was distributed by J. B. Ellis, No. 563 in the North American Fungi, as *Peziza* (Dasysc.) *miniopsis* Ell., n. s. It grew on *Acer rubrum*. Saccardo (5) put it in the subgenus Erinopsis of the genus Erinella. This position was a forced one, since the presence of filiform paraphyses naturally excludes the fungus from the genus Erinella, in which genus the paraphyses are lance-shaped. Ellis' New Jersey collection and our Michigan specimens are alike. Both have hairy sessile apothecia, filiform paraphyses, and filiform spores. These characters place the fungus in the genus Dasyscyphella.

Dermatea balsamea (Pk.) Seaver. — On balsam sticks, Harbor Springs, June 3, 1933, A. H. Smith (S. 33–121).

Epiglia gloeocapsae Boud. — On mat of wet leaves, Dexter, June 28, 1930, B. B. Kanouse (K. 376). This species is beautifully illustrated by Boudier (1, Pl. 454). The small hyaline pulvinate apothecia are inconspicuous on the wet leaves. Microscopic sections reveal the interesting and distinctive characters, particularly the numerous paraphyses curled at their apices. The spores are ellipsoid, measure 10–13 × 7–8 μ, and contain two guttulae.

Helotium limonium C. & P. — On rotten stick, Ann Arbor, Oct., 1931, B. B. Kanouse (K. 255). The apothecia are cream-colored to pale yellow and are powdery externally.

Lachnea stercorea Gill var. **microspora,** var. nov.[5] On dung, Halbert, Aug. 27, 1933, E. B. Mains and A. H. Smith (M. 33–522). The apothecia are like those described for the species in all

[5] *Lachnea stercorea* Gill var. **microspora,** var. nov. — A forma typica differt sporis minoribus 11–13 × 6–7 μ. Specimen typicum in fimo legerunt. A. H. Smith et E. B. Mains prope Halbert, Michigan. In Herb. Univ. Mich. conservatum est sub numero 33–522.

respects except the spore size. The spores in the variety measure 11–13 × 6–7 μ, whereas in the species they measure 18–24 × 9–14 μ. Both the unbranched and the stellately branched hairs that are found in the species occur in the variety.

Lachnum clandestinum (Bull.) Karst. — On *Pteris aquilina*, Rock River, June 10, 1933, E. B. Mains (M. 33–147). This fungus has been reported from Michigan previously by the writer, but is mentioned again since this particular collection showed unusually well developed crystals at the tips of the hairs. The presence of crystals on the hairs, though not common, was noted by Phillips (4), who mentions having found them in *P. clandestinum* Bull. Exceptionally beautiful cruciform crystals were also observed by the author on a fungus collected by Dr. A. H. Smith (S. 648) at Moxham, New York, on *Myrica Gale* L. In the attempt to identify this New York fungus a comparison was made with *Peziza* (*Dasyscypha*) *sulphurella* Pk. at the New York State Museum at Albany. In Dr. Peck's material, which was also collected in New York on *Myrica Gale*, the cruciform crystals were abundant on the hairs. Apparently this same fungus was collected in Canada recently by Dr. H. S. Jackson, who sent it to Dr. F. J. Seaver for identification. Dr. Seaver (6) identified the specimens as *Dasyscypha crucifera* (Phill.) Sacc. This name was given to an English collection which likewise grew on *Myrica Gale*. The cruciform crystals described by Phillips called forth a lively discussion between Cooke (2) and Phillips (4). Strangely enough, Peck's description of *P. sulphurella* was published in the same month of the same year as was Phillips' description of *P. crucifera*. The preprint which contains Peck's description bears the following data on the title page: "From the Thirtieth Annual Report of the New York State Museum of Natural History for the year 1876," and "Published September 1878 in advance of the Report." Phillips' description appeared in the *Gardeners' Chronicle* for September 28, 1878. The two New York collections and the Canadian collection, all of which have been examined by the writer, appear to be exactly like the English fungus.

Lamprospora wisconsinensis Seaver. — On soil, Saginaw Forest, University of Michigan, Ann Arbor, A. H. Smith (S. 5071).

Mollisiopsis euparaphysata (Schröt.) Rehm. — On *Carex sp.*, Delhi, May 20, 1933, A. H. Smith (S. 33–74). This is a minute

plant that when dry resembles a sand grain. The lance-shaped paraphyses are a conspicuous feature of the species.

Ombrophila microsperma P. Henn. — On decaying stems of grass in seepage from a beaver dam, Big Bay, June 13, 1933, E. B. and E. E. Mains (M. 33–304). This is a very small fungus. The apothecia measure less than 1 mm. in diameter. On drying they flatten down to thin scales and are difficult to find. The spores measure 7–8 (9) × 1.5–2 μ.

Phialea caulicola (Fr.) Rehm. — On stems of *Urtica sp.*, Rock River, June 14, 1933, A. H. Smith (S. 33–489).

Sphaerospora brunnea (A. & S.) Rehm. — On burnt soil, Muskegon, Oct. 11, 1936, A. H. and H. V. Smith (S. 5014).

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OBSERVATIONS ON SPECIES OF BULLIARDELLA *

MARION L. LOHMAN

UNLESS carefully searched for, the majority of the species of hysteriaceous fungi which inhabit conifers remain unobserved even when twigs, bark, and wood are examined in the study of other fungi. Characterized by vertically compressed ascigerous fructifications which simulate miniature bivalves, they are of the genera Lophium, Mytilidion, and Bulliardella. Some of the species have come to be of particular interest because of the unexpected life cycles which they have shown in culture; others, for the fact that they are affording additional data for those who see a similarity of species in the fungi of our northern forests and the forests of northern Europe.

These notes report a study of the little-known American fungus described by Cooke and Ellis (3) as *Glonium nitidum* Ellis; also, the occurrence in the White Mountains of the equally little-known species *Hysterium sphaerioides* Karst. (referred to Bulliardella by Rehm), which has been found on birch only in northern Europe. These species are within the limits of the genus as it has been recognized in Europe, that is, without considering our tropical Ostreionella, lately treated under Bulliardella by Clements and Shear (2). They properly add to North American fungi a genus which heretofore appeared to be strictly European.

The little that has been published on Bulliardella is rather contradictory. Consequently in the present study it has been necessary to consider all European species of the genus.

REVIEW OF THE GENUS

Bulliardella, in the sense of its type species, *B. Baccarinii* Paoli, is of the family Mytilidiaceae of Kirschstein (7), or of the Hysteriaceae

* For the opportunity to study type specimens of *Bulliardella Sabinae* Kirschst. and *Hysterium sphaerioides* Karsten I am especially indebted to Professor W. Kirschstein of Berlin and Professor Harald Lindberg of Helsingfors, respectively.

of most authors. The name was proposed by Saccardo (*Sylloge fungorum*, Vol. II. 1883) and used subgenerically under Mytilidion to accommodate a species *M. lineare* Rehm (Ascom. No. 216, with diagnosis; 1881) which was peculiar to that genus because of its two- rather than many-celled ascospore and not readily classified under Glonium in his system because of its conchiform fructification and yellow to brown spores. In 1905, first Paoli (10) and then Saccardo (*Sylloge fungorum*, Vol. XVII) gave the name generic rank in considering the species *B. Baccarinii*. Soon after Rehm (11) referred both species to an earlier name, *Hysterium sphaerioides* Karsten (5 6), bringing it under Bulliardella. Kirschstein (7) later described as new another European species, *B. Sabinae*.

Quite like these European species on conifers is *Glonium nitidum* Ellis, which has been recognized on coniferous hosts in North America since 1879. It differs from Rehm's *Mytilidion lineare* largely in host relationship; from *Bulliardella Baccarinii* Paoli, in size of hysterothecia, asci, and ascospores; from *B. Sabinae* Kirschst. in habitat and development of the fructifications; and from *Hysterium sphaerioides* Karst. in host relationship and general morphology.

NOTES ON AUTHENTIC SPECIMENS

With respect to *Glonium nitidum* Ellis, a careful study was made of No. 570, Ellis, N. Am. Fungi, and No. 1333, Ellis and Everhart, Fungi Columb., in both the Farlow Herbarium and University of Michigan Herbarium, to determine relative uniformity of hysterothecia and spores. These materials were found to be identical and in conformity with the descriptive notes by Bisby (1) on authentic specimens in the Kew Herbarium.[1]

The fructifications in these specimens on the bark of Chamaecyparis are elliptic-linear, up to 0.4 mm. in length, *subconchiform with thin prosenchymatous walls convergent in a sharp crest*, as in each of the three European species of Bulliardella found on coniferous substrata. The spores (Fig. 1 *A*, *B*) are yellowish hyaline to clear brown, uncon-

[1] Bisby, *op. cit.*, regards as identical distribution No. 570 [270] and a specimen (No. 3016, which was cited in the original description) from the Cooke collection which appears to be type or cotype material. In considering color of spores alone, he perhaps justifiably retains the species under Glonium. It is upon consideration of host relationship, shape, and hyphal structure of the fructifications and shape and color of spores that the fungus appears as an American counterpart of some European species of Bulliardella.

stricted, elliptic-clavate, slightly curved, and measure (6) 8–10 × 2.7–3 μ. In these features the fungus appears to be rather closely allied with *Mytilidion lineare* Rehm as known to the writer through a study of the original collection on decorticated pine wood (Rehm, Ascom. No. 216; Farlow Herbarium). However, in Rehm's specimen the fructifications are more densely aggregated, a little shorter, measuring up to 0.3 mm., and the ascospores are noticeably narrower, measuring 10–12 × 2–2.5 μ. In size of hysterothecia and spores *M. lineare* and *Bulliardella Sabinae* may be compared favorably, al-

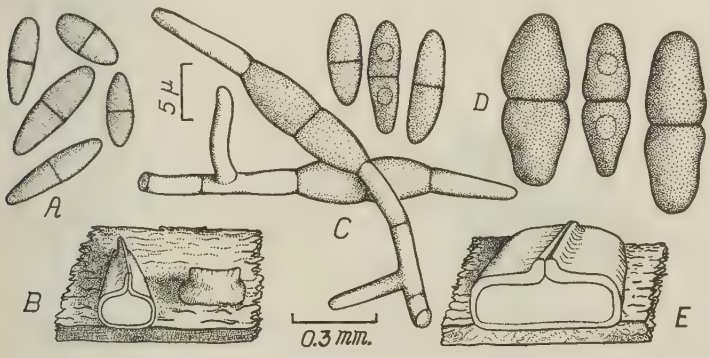

Fig. 1. Ascospores, as outlined with the aid of the camera lucida and diagrams of fructifications in illustration of *Bulliardella nitida* (Ellis) Lohman (*A*, *B*, N. Am. Fungi, No. 570, and *C*, Wisconsin collection, No. 312) and *Bulliardella sphaerioides* (Karst.) Rehm (*D*, *E*, original Karsten specimen). The approximate magnifications of the figures are, respectively, × 1600 and × 40, as may be determined from the absolute scales shown

though there is further diminution in the latter, wherein the fructifications are up to 0.25 mm. long and the spores measure (9) 10–12 × 2 μ; yet the foliicolous habit of *B. Sabinae* on a member of the Cupresseae is so much in contrast to the lignicolous habit of *M. lineare* on a member of the Abieteae that any close relationship between these species seems improbable. The small fructifications with their poorly developed basal walls would appear to constitute a rather definite specialization in conjunction with an obligate foliicolous habitat.

According to Paoli (10), the fructifications in the original collection of *Bulliardella Baccarinii* are on bark of Thuja, collected in Tuscany. They are elliptic-linear, up to 1 mm. long, *conchiform and*

fragile (thus undoubtedly prosenchymatous). As described by Paoli the fructifications, asci, and spores are about as large again as in either *Glonium nitidum* Ellis or *Mytilidion lineare* Rehm.

The fungus on decorticated Betula (Pl. I), described by Karsten (5) in 1871 under the name *Hysterographium sphaerioides* (Nyl.?) and later (6) under the name *Hysterium sphaerioides* Karsten, which Saccardo recorded with the remark, "An Glonium?", differs from those on coniferous substrata in several important morphological features (Fig. 1 *D*, *E*) as well as in its host relationship. Of first importance is the fact that the walls of the fructifications are *thick and parenchymatous.*

The specific data related above for the five type specimens indicate, in the writer's opinion, that as many species are concerned. However, it is hoped that the status and relationships of these fungi can be further investigated, especially with regard to cultural characteristics. Until now only the American species *Glonium nitidum* has been studied in culture. Isolation of *Bulliardella sphaerioides* was attempted with the material from New England, but the ascospores were not viable.

CULTURAL CHARACTERISTICS OF *BULLIARDELLA NITIDA*

Three specimens (Nos. 172, 312, 315) which agree with Ellis' distribution of *Glonium nitidum,* No. 570, N. Am. Fungi, have been available for cultural studies.[2] Ascospores of No. 172 failed to germinate in repeated attempts, but from Nos. 312 and 315 eleven monosporic and five single-ascus isolations were obtained in 1931. These were grown on maltose-malt extract, oatmeal, Kauffman's synthetic, and Bacto Corn Meal agar media in comparison with certain other species for which cultural characteristics have been reported (8, 9), particularly *Mytilidion laeviusculum* (Karst.) Sacc., *M. australe* Lohman, *M. Thujarum* (C. & P.) Lohman, and *M. scolecosporum* Lohman. The media mentioned, with the exception of standard Bacto Corn Meal, were prepared according to recipes already published (8).

[2] No. 172: on *Thuja occidentalis* L., October, 1929, Ann Arbor, Michigan; in the writer's collection. Nos. 312, 315: on *Thuja occidentalis* L., September, 1930, Red Banks, Wisconsin (A. H. Smith); in the University of Michigan Herbarium, in the Farlow Herbarium, Harvard University, and in the writer's collection. Ascospores in No. 312 are identical with those in Ellis' No. 570 (Fig. 1 A–C); in No. 315 they are up to 12 μ in length.

All cultures of this species were strikingly uniform and produced only sterile mycelia, with no coloration of the media. The mycelial mats developed in the form of deep, even, compact velvety cushions, brownish black within; externally, grayish but becoming light brown with age. On oatmeal and cornmeal media the mats were least erumpent, and smooth with brownish to black margins at the surface of the medium, giving them a bordered appearance. In vegetative cultural characteristics the species is grouped with *Mytilidion tortile* (Schw.) Sacc., *M. Thujarum* (C. & P.) Lohman, and *M. resinicola* Lohman, being most nearly like the last except for slower radial growth, rather than with *M. laeviusculum* (Karst.) Sacc., which in morphological features would appear to be closely allied with the conifer-inhabiting species of Bulliardella (Pl. II *B*).[3]

Thus in cultural as well as in morphological features *Glonium nitidum* appears to be closely allied with conifer-inhabiting species of Kirschstein's family Mytilidiaceae. It is proposed, therefore, that this fungus be designated by the new combination, *Bulliardella nitida* (Ellis) Lohman.

DESCRIPTIONS OF SPECIES KNOWN TO OCCUR IN THE UNITED STATES, WITH NOTES

The following technical descriptions based on authentic specimens will serve to identify the two species of Bulliardella known to occur in the United States.

1. **Bulliardella nitida** (Ellis), comb. nov. (Fig. 1 *A*, *B*; Pl. II *A*)

(*Glonium nitidum* Ellis ex Cooke & Ellis, *Grev.*, 8: 13. 1879)

Hysterothecia superficial, membranous-carbonaceous, scattered or densely aggregated, elliptic-linear, up to 0.4 mm. long and 0.15 mm. broad, subconchiform with a narrow conspicuous crest, the walls thin and prosenchymatous, fragile when dry, pliable when wet; asci cylindric, 45–60 × 3.5–4.5 μ, with delicate, simple, or sparingly branched paraphyses; ascospores obliquely uniseriate, elliptic-clavate, slightly curved, mostly unconstricted, yellowish hyaline to clear yellow brown, (6) 8–10 × 2.5–3 μ. — Diagnosis based upon Ellis, N. Am. Fungi,

[3] The records of radial growth at two months on the oatmeal medium average 21 mm. for cultures held at 10° C. and 24 mm. for those at 20°. Growth rates and cultural aspects of the four species referred to have been published (8).

No. 570, which, according to Bisby (1), compares favorably with the type specimen.

On bark of Chamaecyparis; New Jersey.

This species occurs on bark of Chamaecyparis, Juniperus, and Thuja; New Jersey, New England, and westward, probably throughout the region of the Great Lakes (see footnote 2).[4] The fructifications are more or less hidden by shreds of the outer bark.

Aside from the apparent immaturity of the type material the species appears to be fairly uniform in measurable features. However, there is a specimen in the Farlow Herbarium (Thaxter: Waverley, Mass., 1887), collected on Juniperus, in which the asci are slightly larger than described above and the ascospores measure (10) 12–14 (16) × 3.5–4.5 μ. It is clear in the notes on authentic specimens that extreme variability in measurable features and habit would result if European species were referred to this name. This species and *B. lineare* (Rehm) are very similar morphologically, yet it is known only on Cupresseae and the latter only on Abieteae. *B. Baccarinii* on Thuja in Italy has hysterothecia, asci, and spores twice as large as in our species, and *B. Sabinae* of Germany differs in its incomplete wall, which may or may not be a response to development on leaf tissue.

2. **Bulliardella sphaerioides** (Karst.) Rehm (11, p. 110) *pro parte* (Fig. 1 *D, E*; Pl. I)

(*Hysterium sphaerioides* Karsten, *Mycol. fenn.*, II: 234. 1873)

Fructifications erumpent to superficial, carbonaceous, densely aggregated, oblong to circular, up to 0.6 mm. long, flattened and with a narrow low ridge, walls thick and parenchymatous, firm even when wet; asci cylindric, 100–110 × 10 μ, with delicate, filiform, branched paraphyses, the hymenium with a pinkish tinge; ascospores obliquely uniseriate, biconical with somewhat rounded ends, of two pyriform cells, deeply constricted, pale yellow to rich brown, with or without guttulae, (14) 15 16 (17) × (4) 5 6 μ. — Diagnosis based on the type specimen (Karsten: Betula; Särkjärvi, September 20, 1867) at Helsinki.

[4] Fink and Fuson (4) have recorded *Glonium nitidum* Ellis as occurring in a woodlot near Crawfordsville, Indiana. The specimens (Fink: No. 176, Farlow Herbarium and University of Michigan Herbarium) are immature *Glonium abbreviatum* (Schw.) Lohman, on decorticated wood of *Fraxinus*.

On decorticated dead stem of birch, Twin Mountain, New Hampshire, occupying in association with some Lophiostoma the callus ridges of an old canker probably caused by *Nectria galligena* Bres. (No. 539).

The specimens from New Hampshire compare favorably with the type, even in the pinkish coloration of the hymenium. The fructifications are up to 0.4 mm. long, and ascospores measure 10–12 (14) × 4–4.5 (5) μ. Although the spores are a little shorter, they have the same characteristic shape. In view of the structure of the fructification and host relationship the species probably is not properly classified under Bulliardella. It would appear equally ambiguous if referred to Ostreionella of the West Indies, which is synonymous with Xenolophium of Hawaii. It may be a Schizostoma. As already mentioned, for some reason now unexplainable Rehm (11) considered under this name *Bulliardella* (*Mytilidion*) *lineare* and *B. Baccarinii*.

The present descriptions and the notes on authentic specimens are offered with the hope that they may be of some value to students in obviating any further confusion and reference of the conifer-inhabiting species to the name *Bulliardella sphaerioides* (Karst.) Rehm.

SUMMARY

Two ascomycetous fungi occurring in the United States, one not previously reported, are considered under the genus Bulliardella, which heretofore has been regarded as strictly European. The one, *Glonium nitidum* Ellis of Chamaecyparis, Juniperus, and Thuja, is transferred to Bulliardella in view of its cultural features and its general agreement with authentic specimens of conifer-inhabiting species of the genus. The other, *Bulliardella sphaerioides* (Karst.) Rehm *mutatis charact.*, is reported as having been collected on Betula in the White Mountains of New Hampshire, and the species is described on the basis of Karsten's type. The synonymy of this species as given by Rehm in 1912 is rejected. All species of Bulliardella are reviewed; a fundamental distinction in shape and structure of the fructification and spores between conifer and hardwood species is recognized.

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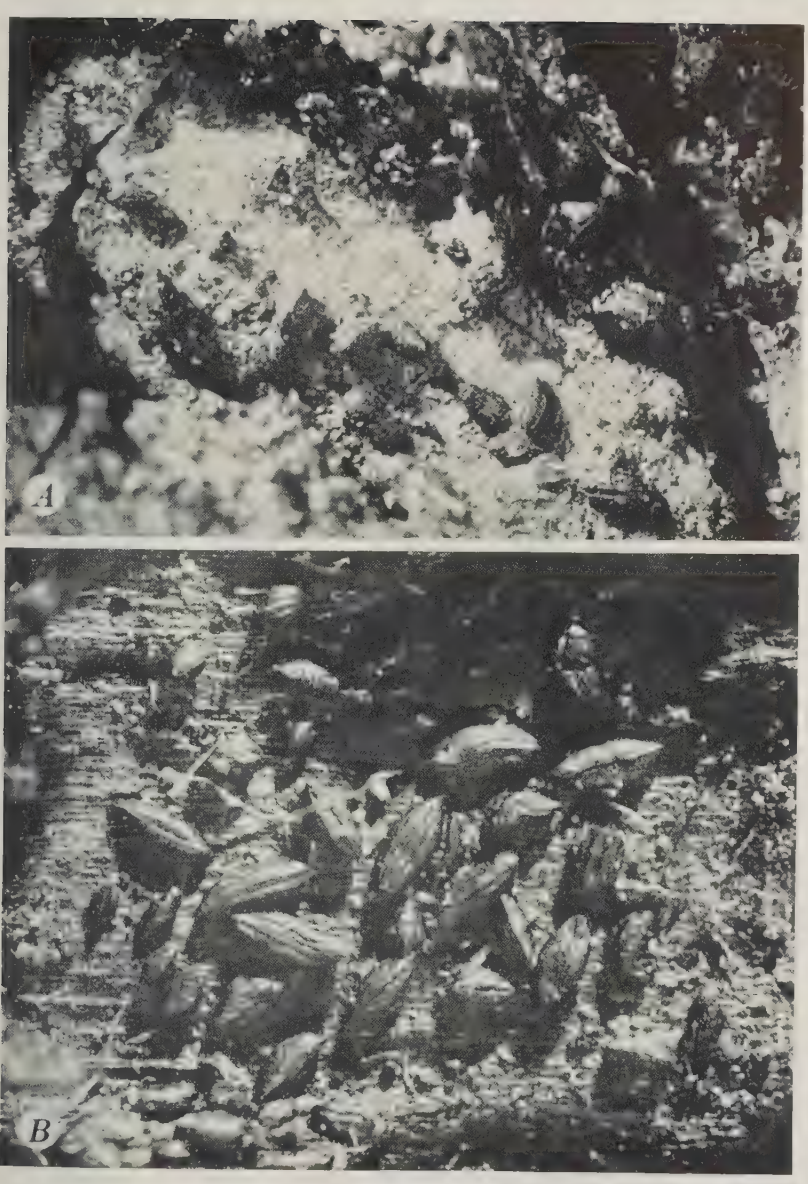
Fructifications of *Bulliardella sphaerioides* (Karst.) Rehm on wood of Betula, a portion of the type specimen in the Karsten collection at Helsinki. × about 30



A. Fructifications of *Bulliardella nitida* (Ellis) Lohman on bark of *Thuja occidentalis* L., Wisconsin collection No. 315. Eight mature fructifications are scattered on the light diagonal area. × about 30

B. Fructifications of *Mytilidion laeviusculum* (Karst.) Sacc. on decayed wood of *Larix laricina* (Du Roi) Koch, from collection No. 281, made near Ann Arbor, Michigan. × about 30

THE DISTRIBUTION OF SOME LICHENS IN NORTH AMERICA *

JOSIAH L. LOWE

DURING part of the summers of 1933, 1934, and 1935 the writer collected lichens in the Adirondack region of New York State, principally on or about Mt. Marcy near Lake Placid, and at the Archer and Anna Huntington Wild Life Forest Station at Newcomb and the Charles Lathrop Pack Demonstration Forest at Warrensburg, the last two areas properties of the New York State College of Forestry. Some of these collections have been studied, and the present determinations include only those relatively certain and of special interest. In addition a few notes are based upon study of specimens from other herbaria.

Grateful acknowledgment for the loan of specimens for study is made to Dr. E. B. Mains, Director of the Herbarium, University Museums, University of Michigan, and to Dr. D. H. Linder, Curator, Farlow Reference Library and Herbarium of Cryptogamic Botany, Harvard University. Dr. A. H. Magnusson of Göteborg, Sweden, gave constant help in supplying, correcting, or confirming the determinations of specimens sent to him. And Mr. H. W. Hicks of the Lake Placid Club kindly extended certain privileges while collections were being made about Mt. Marcy.

The taxonomic concepts here employed are those of Magnusson (9) for the genus Acarospora, of Vainio (16–18) for the Lecideaceae and Calicieae, and of Zahlbruckner (19) for the remainder. All measurements were made from mounts immersed in 3 per cent KOH solution, and colors were checked against duplicate mounts in distilled water. In the following list *Calicium pusillum* var. *parasitaster*, *Lecanora morioides*, and *Rhizocarpon reductum* are reported for the first time from North America, and the known range of the other species is extended.

* Paper from the Department of Forest Botany and Pathology, New York State College of Forestry at Syracuse University, Syracuse, New York.

List of Species

Acarospora americana H. Magn. — On a rock face along Avalanche Lake near Lake Placid, determination by Dr. Magnusson who reported (9–10) the plant from Illinois, Iowa, Nebraska, North Dakota, Colorado, California, New Mexico, and Mexico. It resembles *A. fuscata* (Nyl.) Arn., but, according to Magnusson (9), is distinct by reason of the "non-lobate areolae, a negative C–reaction and a pale lower side."

Acarospora sinopica (Wnbg.) Kbr. — On exposed rocks, Mt. Marcy, elev. 4,900–5,200 feet, and on rocks along the Hudson River at Warrensburg, elev. 700 feet. The life conditions differ exceedingly in the two stations, and it is unusual that a rare species can adapt itself to such a wide variation. Tuckerman (15) reported the plant on "alpine rocks, White Mountains," and Merrill (13) noted it from two stations in Maine.

Acarospora smaragdula var. Lesdainii (Harm.) H. Magn. — On a rock face in a gully along Marcy Brook below Indian Falls, near Lake Placid, the station at an elevation of 3,400 feet. The only North American station given by Magnusson (9) is in California; the species is reported, however, from Maine, Massachusetts, Kentucky, and Alaska. Fink (6) placed the species in synonymy with *A. cervina* (Ach.) Mass., but Magnusson (9) states:

> "Besides the morphological characters there are also microscopical and chemical ones, viz. the broken gonidial stratum, the high hymenium, the distinct excipulum, the thin paraphyses, the narrow spores, the hymenial reaction with I and the thalline KOH-reaction, which make it very distinct."

The confusion of the identities of *A. smaragdula* (Wnbg.) Th. Fries and *A. cervina* is explained by Magnusson.

Bacidia endocyanea (Tuck.) A. Zahlbr. — On conifer bark, Chapel Pond, near St. Huberts. On direct comparison this collection agreed in detail with the only other known, the original one from New Bedford, Mass., collected and described by H. Willey. The following description was drawn from the original collection, now in the United States National Herbarium at Washington, D.C., loaned for study by Dr. W. R. Maxon.

Thallus thin, membranaceous or sometimes slightly thickened

and subverruculose, olivaceous-whitish or pale olivaceous, "cinerescent" (Willey), IKI minus, KOH minus. Apothecia without contained gonidia, solitary or occasionally few-conglomerate, adnate to moderately or sometimes strongly constricted below, 0.3–0.35 (0.55) mm. in diameter, the disk at first plane or rather plane, becoming moderately convex or occasionally varying to hemispherical, black, subshiny, bare, the margin sometimes visible, black, plane, thin, soon disappearing. Hypothecium above intense blue-black, below paler, blackish, in IKI minus, in KOH greenish black, in HNO_3 (5 per cent solution) purple, the hyphae radially arranged above, below irregularly arranged and highly gelatinized, with dark matter in the interstices. Exciple often poorly developed, of radially arranged, highly gelatinized hyphae with dark matter in the radial interstices. Hymenium 55–60 μ high, pale blue-black throughout, in KOH greenish black, in HNO_3 purple except for the blue-black epithecium, in IKI asci walls only blue; paraphyses rather easily separable, unbranched or once-branched, the wall gelatinized, lumen equal throughout, about 1.5 μ across. Asci narrowly clavate, moderately thickened above, 50 × 13–16 μ. Spores hyaline, 8, septa usually indistinct but up to 6 seen, acicular, 20–40 × 2–3 μ, ".022–36 by .002–4 mm." (Willey).

Bacidia flavovirescens (Dicks.) Anzi. — Frequent in a sterile condition at higher elevations (4,700–5,300 feet) on Mt. Colden, Mt. MacIntyre, and Mt. Marcy, the specimens from the last two stations collected by Mr. Alton West. At lower elevations (2,900–3,300 feet) the plant grows on moss over boulders along the brooks and was found twice with apothecia. Fink (6) reported it from the White Mountains, New Hampshire.

Calicium pusillum var. parasitaster Bagl. & Carest. — On squamules of the primary thallus of *Cladonia incrassata* Floerk. at Newcomb. The fruiting bodies appear only on the killed and whitened squamules. The stipe is black, shiny, long and slender, tapering upward (length up to 1 mm.; diam. below 0.04–0.07 mm., above 0.03–0.05 mm.), without a hyaline cover, the hyphae parallel-arranged, strongly coherent, 2.5 3.5 μ in diameter, the wall thick; heads turbinate when young, becoming turbinate-lenticular or rarely lenticular, black, 0.08–0.15 mm. in diameter, the disk black, soon convex; hypothecium hyphae radially arranged:

no mazaedium formed; paraphyses distinct, abundant, strongly coherent, variable, some uniform, others irregular and crooked, 1.5–2.5 μ in diameter, above equal or slightly thickened. Asci 35–40 × 3–3.5 μ, the spores arranged end to end or somewhat obliquely. Spores pale but distinctly brown under the microscope, plainly 1-septate, oblong-ellipsoid or oblong with the ends rounded, occasionally slightly curved, not constricted at the septa, 5–7 (8) × 2–2.5 μ. Stem and head KOH minus.

Some discrepancies appear on comparison with the original description (3). The disk was described as "plano," the stipe as "brevi," and — the most serious — the spores as "ellipsoideae, non numquam levissime incurvatae, . . . 0,007–9 mm. longae, 0,003–4 mm. crassae." The size of the spores of the Newcomb plant agrees better with that of the species ("long. 0,006–0,008, crass. 0,0025–0,003 mm.") as given by Vainio (17) under the synonymous name *Embolidium Italicum* Sacc. The variety was described from plants growing on *Cladonia deformis* Hoffm. in the Tirol near Riva in northern Italy, and later Arnold (1) compared with it a Calicium growing on the squamules of *Cladonia digitata* Schaer. in the Tirol near Paneveggio.

Chaenotheca melanophaea (Ach.) Zwackh. — On old wood, Newcomb. Known elsewhere in North America from Michigan only (8) since Tuckerman (14) corrected his earlier report of this species. The thallus varies from white to greenish gray and it usually gives a pale violaceous stain in KOH, but in one collection the thallus reaction was entirely minus.

Lecanora morioides Blombg. — Inconspicuous and easily passed over, though frequent on hard vertical rock faces; summit of Mt. Marcy, elev. 4,900–5,300 feet. Zahlbruckner (19) reported this species from Europe only.

Mycoblastus alpinus (E. Fries) Kernst. — On conifer bark, Mt. Marcy, elev. 4,600 feet. Reported elsewhere in North America: from Labrador by Arnold (2), from Michigan by Hedrick and Lowe (8), from Washington by Magnusson (11), and from Alaska by Hedrick (7).

Parmelia encausta (Sm.) Ach. – On rock, summit of Mt. Marcy, elev. 5,300 feet. Sterile. Reported by Tuckerman (15) from Greenland, the White Mountains, and Colorado.

Placynthium flabellosum (Tuck.) A. Zahlbr. — On rock in a

brook bed, Newcomb. The apothecia reach an extreme size of 1 × 1.5 mm., much larger than in the original material (0.3–0.55 mm. in diameter). The original plants from New Hampshire and Vermont have been studied and an additional station in Minnesota is cited by Fink (6).

Rhizocarpon lavatum (Ach.) Hazsl. and f. ferratum (Nyl.) Malme. — On rocks along the bed of Marcy Brook below Indian Falls, near Lake Placid, the stations at an elevation of 3,200–3,400 feet. The species determination was approved by Dr. Magnusson and the form recognized by him from misdetermined material. Since Tuckerman did not recognize this species in his *Synopsis* (15) his earlier report (14) may be dismissed; Merrill (12) reported the species from Maine and Vancouver, and the forma from Maine.

Rhizocarpon obscuratum (Ach.) Mass. — On rocks, summit of Mt. Marcy, elev. 5,300 feet. Reported by Eckfeldt (4) from Newfoundland or Labrador, by Fink (5) from Minnesota, and by Merrill (12) from Maine. This species is closely related to *R. lavatum*, and Vainio (16) placed the latter as a forma under *R. obscuratum*; here they are kept separate for the sake of clarity in the distribution records.

Rhizocarpon Oederi (Web.) Koerb. — On rocks at Newcomb, elev. 1,800 feet. The plant usually occurs at higher elevations; Fink (6) reported it "on rocks, at high elevations, Maine, New Hampshire, Oregon, and California."

Rhizocarpon plicatile (Leight.) A. L. Smith. — On rocks, Chapel Pond near St. Huberts, and frequent at Newcomb. Known elsewhere in North America: from West Virginia from an unreported specimen in the Farlow Herbarium, collected by Dr. A. W. Evans and determined by Miss Rose Meyrowitz; also reported by Eckfeldt (4) under the name "*Buellia coniopsoideum* (Hepp.) Eckf." from Labrador or Newfoundland. Zahlbruckner (19) included in synonymy Eckfeldt's report of *Buellia rubescens* (Arn.) Eckf., surely an error since Eckfeldt's plant is described as having bilocular spores and growing on bark. The spores of this species are described by Vainio (16) as "submurali-divisae . . . septis transversis vulgo 5 6, loculis nonnullis septo uno longitudinali obliquove divisis," but in the American material examined and in Arn. Exs. No. 854 (cited by Vainio) the spores usually show 1–2, occasionally 3, longitudinal divisions. The KOH reaction

of the thallus (first yellow, then reddish or reddish brown) and its distinctive habit serve to distinguish the species.

Rhizocarpon reductum Th. Fries. — On rock in a field at Warrensburg; the determination approved by Dr. Magnusson. Zahlbruckner (19) reports the species "in regionibus magis temperatis hemisphaeriae septentrionalis," but no American collections or published records have been seen.

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HOST SPECIALIZATION IN *COLEOSPORIUM SOLIDAGINIS* AND *C. CAMPANULAE* *

EDWIN B. MAINS

I. COLEOSPORIUM SOLIDAGINIS

ARTHUR (2) lists 126 species in 16 genera of the Compositae as hosts for *Coleosporium Solidaginis* (Schw.) Thüm. in North America. Stimulated by differences in infection noted in the field, especially between associated species of Aster and Solidago, the writer conducted experiments from 1931 to 1934 to determine the host specialization of this rust from different sources. A number of the species of Solidago used in these studies were received from Professor J. H. Ehlers, University of Michigan. Other species were obtained locally or from various botanical gardens; the identifications were verified when the plants blossomed.

The rust was studied from three hosts collected in the vicinity of Ann Arbor. These were *Solidago canadensis*, *Pinus resinosa*, and *Aster novae-angliae*.

A. Rust from *Solidago canadensis*

To the rust from *Solidago canadensis*, *S. canadensis* L. (4 strains),[1] and *S. juncea* Ait. (3 strains) were very susceptible. *Aster prenanthoides* Muhl., *Solidago bicolor* L. (3 strains), *S. macrophylla* Pursh, *S. ohioensis* Riddell, *S. patula* Muhl. (2 strains), *S. Riddellii* Frank, *S. rigida* L., and *S. rugosa* Mill. were resistant, although some small uredinia developed. *Aster ericoides* L., *A. laevis* L., *A. lateriflorus* (L.) Britton, *A. macrophyllus* L., *A. novae-angliae* L., *A. novi-belgii* L., *A. paniculatus* Lam., *A. puniceus* L., *A. sagittifolius* Wedemeyer, *Callistephus hortensis* (China aster, mixed varieties), *Solidago Elliottii*

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 632. The inoculation experiments were made possible through facilities furnished by the University Botanical Gardens.

[1] Unless otherwise indicated, only one strain was used. When several are indicated the stocks originated from seed obtained from different sources.

T. & G., *S. graminifolia* (L.) Salisb., *S. hispida* Muhl., *S. Houghtonii* T. & G. (6 strains), *S. neglecta* T. & G., and *S. nemoralis* Ait. (4 strains) were highly resistant, either being without evidence of infection or showing only flecking with a few small uredinia. Variable results were obtained with a few species. The strains studied of *Solidago sempervirens* L., *S. serotina* Ait., *S. ulmifolia* Muhl., and *S. uliginosa* Nutt. contained both resistant and susceptible plants. Three strains of *Solidago altissima* L. were very susceptible, and one was moderately resistant. One collection of *Solidago speciosa* Nutt. was very susceptible; one was moderately resistant.

B. Rust from *Pinus resinosa*

In 1933 *Pinus resinosa* in the plantings of the Forestry School, west of Ann Arbor, was heavily infected with the aecial stage of *Coleosporium Solidaginis*. Inoculations were made with the following results. *Solidago canadensis* (3 strains), *S. juncea*, *S. ohioensis*, *S. rigida*, and *S. rugosa* were very susceptible; *S. ulmifolia* was moderately susceptible. *Solidago patula*, *S. serotina*, *S. speciosa* (2 strains), and *S. uliginosa* were moderately resistant. *Aster ericoides*, *A. laevis*, *A. lateriflorus*, *A. macrophyllus*, *A. novae-angliae*, *A. novi-belgii*, *A. paniculatus* (2 strains), *A. puniceus*, *A. sagittifolius*, *Callistephus hortensis* Cass. (China aster, mixed varieties), *Solidago Elliottii*, *S. graminifolia*, *S. neglecta*, and *S. nemoralis* (2 strains) were highly resistant. One strain of *Solidago bicolor* was highly resistant; the other was highly susceptible. The latter was highly resistant to the rust from *S. canadensis*. *Solidago altissima*, *S. Houghtonii*, *S. juncea*, and *S. sempervirens* showed variable results similar to those noted for the rust from *S. canadensis*.

C. Rust from *Aster novae-angliae*

Inoculations were made from heavily rusted plants of *Aster novae-angliae* collected in 1933. *Aster novae-angliae*, *A. Lindleyanus* T. & G., and *Callistephus hortensis* (China aster, mixed varieties) were very susceptible. *Aster laevis*, *A. puniceus*, and *Solidago speciosa* were moderately resistant. *Aster ericoides*, *A. lateriflorus*, *A. macrophyllus* (2 strains), *A. novi-belgii*, *A. paniculatus* (2 strains), *A. prenanthoides*, *A. sagittifolius*, *Solidago altissima*, *S. bicolor* (2 strains), *S. canadensis* (3 strains), *S. Elliottii*, *S. graminifolia*, *S. Houghtonii*, *S. juncea* (3 strains), *S. neglecta*, *S. nemoralis* (2 strains), *S. ohioensis*,

S. patula, S. rigida, S. rugosa, S. serotina, S. uliginosa, and *S. ulmifolia* were highly resistant. One strain of *Solidago sempervirens* was highly resistant and the other was moderately resistant.

It is evident that various physiologic races occur in this species. The most marked separation is that between the rust on species of Solidago and that on species of Aster. Species of Aster were not infected to any appreciable extent by the rust which found species of Solidago congenial hosts. The opposite was true for the rust from *Aster novae-angliae.* The rust from *Solidago canadensis* and *Pinus resinosa* found species of Solidago congenial hosts, but did not infect all species in the same manner. *Solidago ohioensis* and *S. rigida* were resistant to the rust from *S. canadensis* and very susceptible to that from *Pinus resinosa.* That other races or forms exist is indicated. In these studies, *Solidago Elliottii, S. neglecta,* and *S. nemoralis* were highly resistant to the rusts from *S. canadensis* and *Pinus resinosa.* Arthur (1) gives these as hosts for *Coleosporium Solidaginis.* However, the differences in reaction noted within such species as *Solidago altissima, S. sempervirens, S. serotina, S. ulmifolia,* and *S. uliginosa* indicate that this might be explained on the basis of strain differences within the host species. It would appear that as complicated a situation exists in this species as in the cereal rusts.

II. COLEOSPORIUM CAMPANULAE (Pers.) Lév.

Coleosporium Campanulae occurs commonly in northeastern United States on *Campanula americana* L. The physiologic specialization of this rust has received considerable study in Europe (see Klebahn, 3). In the European studies, however, *Campanula americana* was not included. Consequently between 1932 and 1934 this investigation of the rust in the vicinity of Ann Arbor, Michigan, was carried out. The results of repeated cultures during the three years may be summarized as follows. *Campanula americana* L., *C. latifolia macrantha* Fisch. (2 strains), and *C. Rapunculus* L. were very susceptible. *Campanula bononiensis* L. was moderately rusted. *Phyteuma spicatum* L. (2 strains) was moderately resistant, the uredinia being small and usually accompanied by some necrosis. One collection of *Campanula Trachelium* L. was moderately resistant and three were highly so, no uredinia developing. *Campanula carpatica* Jacq., *C. medium* L., *C. patula* L., *C. persicifolia* L. (4 strains), *C. pusilla* Haenke, *C. rotundifolia* L. (3 strains), and *C. turbinata* Schott were

highly resistant, no uredinia being produced. Three strains of *Campanula glomerata* L. were studied. One was uniformly highly resistant, two were variable in reaction, some plants being highly resistant, others moderately resistant, with some uredinia developing. Three strains of *Campanula rapunculoides* L. were uniformly highly susceptible; one strain was moderately susceptible. One strain was variable, giving highly susceptible, moderately resistant, and highly resistant plants. These were grown to maturity, and all proved to be *Campanula rapunculoides.*

Klebahn (3) has recognized three specialized forms and accepts doubtfully two proposed by Wagner. To *Coleosporium Campanulae rapunculoides* he found that *Campanula rapunculoides* was very susceptible; *C. glomerata dahurica* moderately susceptible; *C. glomerata* and *Phyteuma orbiculare* were sparingly infected; *C. bononiensis, C. carpatica, C. latifolia macrantha, C. pusilla, C. rotundifolia, C. Rapunculus, C. Trachelium,* and *C. turbinata* showed no infection. To *Coleosporium Campanulae Trachelii, Campanula Trachelium* and *C. latifolia macrantha* were very susceptible; *C. bononiensis, C. glomerata,* and *C. glomerata dahurica* moderately susceptible; *C. rapunculoides* was sparingly infected; and *C. carpatica, C. medium, C. pusilla, C. persicifolia, C. rotundifolia,* and *C. turbinata* showed no infection. To *Coleosporium Campanulae rotundifoliae, Campanula pusilla, C. rotundifolia, C. turbinata,* and *Phyteuma spicatum* were very susceptible; *C. bononiensis, C. glomerata dahurica,* and *Phyteuma orbiculare* moderately susceptible; and *C. carpatica, C. glomerata, C. persicifolia, C. Rapunculus,* and *C. Trachelium* showed no infection. Wagner (4), with rust from *Campanula macrantha* (*C. latifolia macrantha*), obtained infection on *C. macrantha* and negative results on *C. carpatica, C. patula, C. persicifolia,* and *C. Trachelium.* Aecia originating from rust on *Phyteuma spicatum* infected *P. spicatum* and gave negative results on *Campanula patula* and *C. rotundifolia.*

The results obtained with the rust from *Campanula americana* do not completely agree with those obtained with any of the European specialized forms, and it might be concluded that the American rust is an additional specialized form. The variations noted in several of the species of Campanula, especially *C. rapunculoides,* demonstrate that species of Campanula are not necessarily genetically uniform for rust reaction. In the absence of a certainty of the genetic identity of the strains of the hosts used in different investigations it is not

possible to make accurate comparisons. It is evident that there is a complicated situation somewhat similar to that in the cereal rusts, a situation brought about by the interaction of various factors for pathogenicity of the rusts and various factors governing the reactions of their hosts and various combinations of such factors through hybridization.

The variations observed in the reaction within host species which have been noted in a number of studies indicate that accurate comparisons are not possible unless strains of host species of genetic identity for rust reaction are employed in the different investigations. It is doubtful whether the isolation and the maintenance of such strains of host species are feasible except in long-continued coöperative studies of rusts of considerable economic importance. It is evident that too much emphasis has been placed upon the reaction of host *species* not only in the separation of specialized races but also in the separation of species of rusts.

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NEW SUMATRAN PLANTS. III

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THIS paper is similar to the preceding ones [1] in that it contains descriptions of hitherto undescribed species and records of known species not before reported from Sumatra. Among the latter are representatives of the following genera new to the Sumatra flora: Pseudopipturus, Roureopsis, Taeniochlaena, Dunbaria, Enkleia, Philbornia, and Picria. Twenty species are described as new; the types of some are deposited in the Britton Herbarium, New York Botanical Garden, of others in the herbarium of the Arnold Arboretum. There are isotypes of all in the herbarium of the University of Michigan. The descriptions and records are chiefly based on collections made for Professor H. H. Bartlett by his native collector Rahmat Si Boeea (*alias* Rahmat Si Toroes), and distributed from the University of Michigan, but specimens collected by Yates, Bartlett, Hamel, and Krukoff are also cited.

URTICACEAE

Pseudopipturus mollissimus (Blume), comb. nov.

Urtica mollissima Blume, Bijdr., 501. 1825.
Pipturus mollissimus Wedd., Arch. Mus. Hist. Nat. Paris, 9: 449. 1856; Hook. f., Fl. Brit. Ind., 5: 589. 1888; Ridl., Fl. Malay Penin., 3: 367. 1924.
Pipturus repandus Wedd. var. *mollissimus* Koord. & Valeton, Meded. Dep. Landbouw Java, 10: 729. 1910 (Bijdr. Boomsoort. Java, 12: 729).

SUMATRA, East Coast, Asahan, *Yates 1220;* Silo Maradja, *Bartlett 8435*, April–June, 1927, *Rahmat 55*, Dec., 1927; Hoeta Padang, *Krukoff 4446*, Dec. 4, 1932; Tapianoeli, Hatiran, and Sopsopan, *Rahmat 4747*, *4777*, *4861*, *5138*, June–July, 1933; local name *andor horihori*. Malay Peninsula, Java.

[1] Merrill, E. D., "New Sumatran Plants. I," *Pap. Mich. Acad. Sci., Arts and Letters*, 19 (1933): 149–203, pls. 16–35. 1934; II, *ibid.*, 20 (1934): 95–112. 1935.

ARISTOLOCHIACEAE

Apama sumatrana, sp. nov.

Suffruticosa, caulibus 3–4 mm. diametro, longitudinaliter sulcatis, glabris, partibus ultimis 2 mm. diametro, consperse hirsutis; foliis chartaceis vel subcoriaceis, siccitate pallidis, supra laevibus, glabris, subtus hirsutis, oblongo-ellipticis, acutis vel obtusis, basi latissime acutis vel rotundatis, subtrinerviis, nervis primariis utrinque 8–10, subtus perspicuis, elevatis, secundariis subparallelis cum reticulis ultimis elevatis perspicuis; petiolo 3–4 mm. longo, plus minusve hirsuto; racemis axillaribus et in axillis defoliatis, 3 8 cm. longis, hirsutis, bracteolis numerosis, oblongo-oblanceolatis vel spatulatis, hirsutis, circiter 3 mm. longis, persistentibus; pedicellis saltem 6 mm. longis; perianthi segmentis 3, oblongis vel oblongo-ovatis, 10 mm. longis, 6 mm. latis, acutis vel subacutis, extus parcissime breviter hirsutis, intus glabris, reticulatis; staminibus 6, 1-seriatis, filamentis 1.5 mm. longis, antheris 2.5 mm. longis, anguste oblongis, rostratis; fructibus cylindraceis, circiter 7 cm. longis, 5 mm. diametro, glabris, irregulariter subtorulosis, pedicellis leviter incrassatis, 12 mm. longis.

Sumatra, Tapianoeli, Padang Si Dimpoean, Padang Lawas, Poelo Liman (topographic sheet 41), *Rahmat 5259*, Aug. 17 24, 1933. Allied to *Apama tomentosa* (Blume) Engl., but with elongated stems, more numerous, differently shaped, more numerously nerved leaves, and differently shaped bracteoles. As in other species of the group, apparently only one or two flowers mature at any one time.

CONNARACEAE

Rourea oligophlebia, sp. nov.

Frutex scandens, partibus junioribus et inflorescentiis et subtus foliis breviter pubescentibus, ramis teretibus, glabris, ramulis ultimis circiter 3 mm. diametro; foliis 15–30 cm. longis, foliolis 7 13, oblongis vel oblongo-ellipticis, obtusis vel rotundatis, basi subacutis, obtusis, vel rotundatis, 7 11 cm. longis, 2 4 cm. latis, coriaceis vel subcoriaceis, supra glabris, olivaceis vel pallidis, subtus pallidioribus, breviter consperse pubescentibus, nervis primariis utrinque circiter 4, adscendentibus vel curvato-adscendentibus, subtus elevatis, perspicuis, haud anastomosantibus; inflorescentiis terminalibus, breviter

pubescentibus, paniculatis, elongatis, circiter 25 cm. longis, ramis lateralibus subfasciculatis, circiter 4 cm. longis; floribus numerosis, circiter 4 mm. longis, sepalis oblongo-ovatis vel oblongo-lanceolatis, acuminatis, extus pubescentibus, 3.5 mm. longis; petalis quam sepalis paullo longioribus; filamentis glabris, brevibus; stylis filiformibus, subexsertis, circiter 4 mm. longis; fructibus ellipsoideis, glabris, subaequilateralibus, haud compressis, circiter 2 cm. longis, 1–1.5 cm. diametro, rotundatis vel obtusis, sepalis persistentibus, glabris, coriaceis, accrescentibus, ovatis, circiter 5 mm. longis latisque.

Sumatra, Tapianoeli, Padang Si Dimpoean, Padang Lawas, Hoeta Imbaroe (topographic sheet 41, northwest corner), *Rahmat 4635*, *4912*, June–July, 1933; East Coast, Asahan, Soenggapa to Pargambiran, *Bartlett 8161*, May 22, 1927; Bila, Goenoeng Soeasah, near Rantau Parapat, *Rahmat 2053*, *2342* (type), March–May, 1932; Loemboen Ria and Hoeta Bagasan, *Rahmat 6775*, *7897*, Feb. April, 1934, and Sept., 1934 — Feb., 1935; local name *andor garoenggang*. Characterized particularly by its oblong to oblong-elliptic leaflets, which are obtuse or rounded at both ends and with few conspicuous ascending lateral nerves, as well as by its practically equilateral fruits, which are not at all compressed or falcate.

Roureopsis javanica (Blume) Planch., Linnaea, 23 : 424. 1850.

Connarus javanicus Blume, Bijdr., 1166. 1826.
Rourea javanica Blume, Mus. Bot. Lugd.-Bat., 1 : 262. 1850.

Sumatra, East Coast, Koealoe, Aek Sordang, *Bartlett 2882*, *6894*, March, 1927; Laboehan Batoe, Kota Pinang, and Bila, *Rahmat 2016*, *3279*, *3369*, *3421*, *3506*, *3599*, *3746*, *3813*, *3939*, *4095*, *4147*, *4246*, March–May, 1933; Tapianoeli, Padang Si Dimpoean, Padang Lawas, *Rahmat 4509*, May–June, 1933. Java. A new record for Sumatra.

Taeniochlaena Griffithii Hook. f., in Benth. & Hook. f., Gen. Pl., 1 : 434. 1862; Hook. f., Fl. Brit. Ind., 2 : 55. 1876; Oliv., Hook. Ic., 24 : t. 2392. 1895; Ridl., Fl. Malay Penin., 1 : 554. 1922.

Sumatra, Tapianoeli, Padang Si Dimpoean, Padang Lawas, Sopsopan, on the Aek Si Olip, *Rahmat 5042*, July, 1933. Malay Peninsula. A new record for Sumatra.

LINACEAE

Enkleia malaccensis Griff., Calc. Journ. Nat. Hist., 4 : 234. 1844, *in nota;* Walp., Ann., 1 : 588. 1848–49; Hall. f., Med. Rijks Herb. Leiden, 44 : 24. 1922; Ridl., Fl. Malay Penin., 3 : 147. 1924.

Enkleia malayana Griff., Notul., 4 : 363. 1854.
Linostoma scandens Kurz, Journ. As. Soc. Bengal, 39 (2) : 83. 1870; Lecomte, Fl. Gén. Indo-Chine, 5 : 174. 1915.
Linostoma siamense Kurz, *op. cit.*, 82.

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Si Mandi Angin, *Rahmat 4099*, April May, 1933. Siam, Indochina, Malay Peninsula, and Borneo. A new record for Sumatra.

Philbornea magnifolia (Stapf) Hall. f., Arch. Neerl. Sci., III B, 1 : 110. 1912; Repert. Sp. Nov., 13 : 415. 1914.

Durandea magnifolia Stapf, Hook. Ic., 29 : t. 2822. 1906.

Sumatra, Tapianoeli, Padang Si Dimpoean, Padang Lawas, *Rahmat 5059*, July, 1933. Borneo. This new record for Sumatra is based upon a rather unsatisfactory specimen. The other known species of the genus is *P. palawanica* Hall. f. of the Philippines.

RUTACEAE

Acronychia Porteri Hook. f., Fl. Brit. Ind., 1 : 498. 1875; King, Journ. As. Soc. Bengal, 62 (2) : 215. 1893 (Mater. Fl. Malay. Penin., 1 : 457); Ridl., Fl. Malay Penin., 2 : 348. 1922.

Sumatra, East Coast, Asahan, Loemban Ria, *Rahmat 7975*, Feb.–April, 1935; local name *kajoe modang salik*. Malay Peninsula. The nerves are fewer than in *A. laurifolia* Bl. (= *A. pedunculata* (Linn.) Miq.), and the ovaries and young fruits are glabrous or nearly so.

Evodia sambucina (Blume) Hook. f., ex Koord. & Valeton, Meded. Lands Plant., 17 : 216. 1896 (Bijdr. Boomsoort. Java, 4 : 216).

Philagonia sambucina Blume, Cat. Gew. Buitenzorg, 20. 1823; Bijdr., 250. 1825.
Philagonia procera Blume, ex Nees, Flora, 8 : 125. 1825; DC., Prodr., 2 : 90. 1825.
Philagonia sambucifolia Blume, ex Dode, Bull. Soc. Bot. France, 55 : 701. 1908, *in syn.*
Evodia sambucifolia Dode, *l. c.*

Sumatra, East Coast, Asahan, in the Masihi Forest Reserve, *Krukoff 4248*, Nov. 3, 1932, in primary forest. Java. Koorders and Valeton first published the binomial *Evodia sambucina* (Blume) Hook. f., which escaped the attention of the compilers of *Index Kewensis;* they erred in citing as synonyms the very different *Tetradium trichotomum* Lour. (= *Evodia trichotoma* Pierre) and *Evodia fraxinifolia* Hook. f. Blume actually published this as *Philagonia sambucina* in 1823, but two years later Nees in his extensive and critical review of Blume's early papers published it as *Philagonia procera* Blume, as did de Candolle. It seems that Nees and de Candolle had access to authentic specimens bearing a herbarium name proposed by Blume but abandoned in favor of *P. sambucina* when he actually published. Nees republished many of Blume's descriptions, often amplified, and sometimes with critical notes, since he had access to authentic specimens. It is desirable, therefore, in studying Blume's too briefly characterized species to refer to Nees' redescriptions for supplementary data. Nees' work is more generally accessible than Blume's rare "Catalogus." (See *Flora*, 8 : 97–112, 113–125, 129–160. 1825.)

Evodia megistophylla Merrill, sp. nov.

Ut videtur arbor parva, ramulis et inflorescentiis et foliis subtus molliter pubescentibus, ramulis ultimis circiter 1 cm. crassis; foliis 3-foliolatis, longissime petiolatis, petiolo 22–30 cm. longo, crasso, dense breviter pubescenti; foliolis chartaceis vel subcoriaceis, ellipticis vel late oblongo-ellipticis, acuminatis, basi late acutis, 25–35 cm. longis, 12–14 cm. latis, supra, costa excepta, glabris, olivaceis, nitidis, subtus molliter consperse pubescentibus, paullo pallidioribus, costa crassissima, elevata, nervis primariis utrinque 11–14, subtus elevatis, valde perspicuis, laxis; petiolulis crassis, pubescentibus, 1–2 cm. longis; paniculis axillaribus, pedunculatis, dense pubescentibus, circiter 15 cm. longis, ramis primariis usque ad 7 cm. longis; floribus numerosis, 4-meris, in ramulis ultimis plus minusve confertis, pedicellis dense pubescentibus, 2 mm. longis; sepalis extus dense pubescentibus, ovatis, acutis, 1 mm. longis; petalis extus in partibus medianis adpresse pubescentibus, elliptico-ovatis, acutis, 2.5–3 mm. longis; filamentis 4 mm. longis; disco dense pubescenti.

Sumatra, East Coast, Asahan, near Loemban Ria, *Rahmat 7415*, *7504* (type), *7501*, Feb.–Sept., 1934; local names *kajoe modang giak*,

kajoe modang siak. This form, characterized by its very large, long-petioled leaves, which are laxly and very prominently reticulate beneath, and by its indumentum, has been confused with the collective species, *Evodia latifolia* DC., the type of which was an Amboina plant described and illustrated by Rumphius. The present species is represented by a number of Rahmat's earlier collections, including *277* from Bila, *7603*, *1391* from Koealoe, and *5298* from Tapianoeli. Although de Candolle's species is currently supposed to have a very wide distribution within Malaysia, I have no evidence that the form Rumphius originally described occurs in either Sumatra or the Malay Peninsula. To judge from Koorders and Valeton's amplified description of *Evodia accedens* Bl., this Sumatran species is allied to the latter rather than to *E. latifolia* DC.

Clausena platyphylla Merrill, sp. nov.

Arbor parva, novellis et foliis junioribus ad costam nervosque obscure puberulis, glabrescentibus, ramis teretibus, glabris, ultimis 4 mm. diametro; foliis 55–65 cm. longis, pinnatis, foliolis circiter 10, inter se 2–10 cm. distantibus, chartaceis, oblongis vel oblongo-ovatis, leviter inaequilateralibus, integris vel obscure irregulariter dentatis, apice tenuiter acute acuminatis, basi acutis, junioribus utrinque ad costam nervosque puberulis, vetustioribus glabris, 14–18 cm. longis, 5–9 cm. latis, siccitate supra subviridibus, nitidis, subtus pallidioribus, glabris, distincte glanduloso-punctatis, nervis primariis utrinque circiter 12, subtus elevatis, perspicuis, juxta ad marginem obscure curvato-anastomosantibus, petiolulis 3–5 mm. longis; paniculis angustis, 15–20 cm. longis, puberulis, pedunculatis, ramis primariis paucis, distantibus, sub anthesin circiter 1 cm. longis, floribus in ramulis ultimis subcymosis; floribus 5-meris, pedicellatis, sepalis acutis, petalis 5, ellipticis, glabris, paucipunctatis, 4 mm. longis, 2–2.3 mm. latis; staminibus 10, filamentis glabris, 2 mm. longis, deorsum planis, 0.5 mm. latis; antheris ellipticis, 1.5 mm. longis; ovario consperse pubescenti, apice glandulis 5 perspicuis albidis coronato; stylis crassis, glabris, 1.2 mm. longis.

Sumatra, East Coast, Asahan, near Hoeta Bagasan, *Rahmat 6623* (type), Sept.–Feb., 1935; local name *sarindan batoe*. Possibly *Rahmat 6935* represents the same species; the specimen is just beyond anthesis, and has subracemose rather than cymose very young fruits.

To be compared with the latter is *Rahmat 1388, 1388a* from Damoeli, Koealoe, Sept., 1928, a form with somewhat narrower leaflets, 3 to 4.5 cm. wide and up to 17 cm. long, and with elliptic, glabrous, prominently glandular fruits 9 mm. long. Possibly allied to *Clausena Forbesii* Engl., type from Sumatra, of which no formal description seems to have been published, indicated by Engler as having leaves about 1 m. long. Of this I have seen no specimens.

ICACINACEAE

Gomphandra dolichocarpa Merrill, sp. nov.

Ut videtur arbor parva, ramulis et inflorescentiis puberulis, ramis teretibus, glabris; foliis subcoriaceis, oblongis vel oblongo-ellipticis, glabris, 16–25 cm. longis, 5.5–8 cm. latis, perspicue acuminatis, basi acutis, siccitate supra olivaceis vel olivaceo-viridibus, nitidis vel opacis, subtus pallidioribus, plerumque pallide brunneo-olivaceis, utrinque glabris, nervis primariis utrinque circiter 10, subtus perspicuis, elevatis, juxta ad marginem perspicue curvato- vel arcuato-anastomosantibus, reticulis laxis; petiolo circiter 1 cm. longo; inflorescentiis axillaribus, densis, puberulis, breviter pedunculatis, dense multifloris, quam petiolo multo brevioribus, cymoso-capitatis; floribus sessilibus vel brevissime pedicellatis, calycibus cupulatis, truncatis, glabris vel obscure pubescentibus, circiter 1.5 mm. diametro; petalis 5, oblongis, glabris, 4 mm. longis, 1 mm. latis, apice inflexis; filamentis crassis, infra antheris barbatis; ovario glabro; fructibus elongatis, leviter curvatis, glabris, perspicue rostratis, 3 cm. longis, immaturis circiter 4 mm. diametro, rostro 5 mm. longo.

Sumatra, East Coast, Asahan, near Hoeta Bagasan, *Rahmat 7603* (type), *7039, 7140, 7107*, Sept.–Feb., 1935; local names *kajoe rawet, kajoe atimang, kajoe barik*. A species characterized by its prominently nerved leaves, its short, dense, subcapitate-cymose, axillary, many-flowered inflorescences, and especially by its elongated rostrate fruits.

SAPINDACEAE

Allophylus Bartlettii Merrill, sp. nov.

Frutex vel arbor parva, glabra vel subglabra, foliis omnino 1-foliolatis, foliolis magnis, integris vel obscure distanter subrepando-dentatis, inflorescentiis axillaribus, racemiformibus, haud ramosis,

petiolum subaequantibus vel paullo longioribus, ramis ramulisque teretibus, consperse lenticellatis, obscure puberulis, ultimis circiter 1.5 mm. diametro; foliis simplicibus, chartaceis, subellipticis vel late oblongo-ellipticis, 18–33 cm. longis, 7–14 cm. latis, perspicue acuminatis, basi late acutis vel paullo decurrenti-acuminatis, margine integris vel sursum distanter irregulariter dentatis vel subrepando-dentatis, dentibus inter se 2–4 cm. distantibus, supra glabris, subolivaceis, nitidis, subtus pallidioribus, ad costam nervosque plerumque obscure puberulis, nervis primariis utrinque circiter 12, utrinque perspicuis, subtus elevatis, curvatis, arcuato-anastomosantibus, secundariis reticulisque perspicuis, elevatis; petiolo puberulo, 2–4 cm. longo; inflorescentiis axillaribus, solitariis, simplicibus, puberulis, 3–6 cm. longis; floribus numerosis, inter minores, circiter 3 mm. diametro, pedicellis puberulis, 1 mm. longis; sepalis concavis, glabris, imbricatis, 1.5–2 mm. diametro; petalis distincte ciliatis; filamentis plus minusve ciliatis; ovario consperse pubescenti.

Sumatra, East Coast, Asahan, near Hoeta Bagasan, *Rahmat 6569*, *6648*, *6797*, *6933* (type), *7267*, Sept., 1934 — Feb., 1935; local names *kajoe indjing*, *kajoe sipi aek*. This species is apparently most closely allied to *Allophylus chartaceus* (Kurz) Radlk. of India. It is distinct from the seven unifoliolate Philippine species and from the four Ceylon ones, and seems to be the first simple-leaved species in the genus to be recorded from the Malay Archipelago proper.

Xerospermum intermedium Radlk., Rec. Bot. Surv. Ind. 3:349. 1907; Pflanzenr., 98 (IV.165):944. 1932; Ridl., Fl. Malay Penin., 1:497. 1922.

Sumatra, East Coast, Asahan, near Hoeta Bagasan and Loemban Ria, *Rahmat 7045*, *8045*, Feb.–April, 1934, and Sept., 1934 — Feb., 1935; local names *kajoe oeltop-oeltop*, *kajoe oeso lokkang*. Burma, Malay Peninsula.

VITACEAE

Ampelocissus cinnamomea (Wall.) Planch., in DC., Monog. Phan., 5:408. 1887.

Vitis cinnamomea Wall., in Roxb., Fl. Ind., 2:483. 1824; King, Journ. As. Soc. Bengal, 65 (2):389. 1896 (Mater. Fl. Malay. Penin., 2:675); Ridl., Fl. Malay Penin., 1:472. 1922.

Sumatra, Tapianoeli, Padang Si Dimpoean, Padang Lawas. *Rahmat 4486, 4516,* May–June, 1933; local name *andor tawar,* Malay Peninsula and, if Ridley be correct in reducing *A. Winkleri* Lauterb., also in Borneo.

Ampelocissus spicifera (Griff.), comb. nov.

Cissus spicifera Griff., Notul., 4 : 693. 1854.
Vitis macrostachya Miq., Ann. Mus. Bot. Lugd.-Bat., 1 : 94. 1863; Laws, in Hook. f., Fl. Brit. Ind., 1 : 650. 1875; King, Journ. As. Soc. Bengal, 65 (2) : 388. 1896 (Mater. Fl. Malay. Penin., 2 : 674); Ridl., Fl. Malay Penin., 1 : 472. 1922.
Ampelocissus spicigera Planch., in DC., Monog. Phan., 5 : 406. 1887.

Sumatra, East Coast, Kota Pinang, Laboehan Batoe, *Rahmat 3428,* March, 1933. Malay Peninsula, Sumatra. There is a specimen, apparently of the original collection on which Miquel's species was based, in the herbarium of the New York Botanical Garden.

GUTTIFERAE

Cratoxylon acuminatum Merrill, sp. nov.

Frutex vel arbor parva, glabra, ramis ramulisque teretibus, gracilibus, ultimis vix 1 mm. diametro, internodiis elongatis; foliis oblongo-ellipticis, basi acutis, apice graciliter acuminatis, chartaceis vel subchartaceis, 4–8 cm. longis, 1.5–2.8 cm. latis, supra olivaceis, nitidis, subtus pallidioribus, haud glaucis, conspersissime glandulosis, nervis primariis utrinque 5 8, distantibus, supra cum reticulis primariis paullo elevatis, subtus distinctis, elevatis, arcuato-anastomosantibus, reticulis primariis laxis, venulis intra reticula ultima 2–4 mm. lata liberis; petiolo circiter 5 mm. longo; floribus ignotis; fructibus axillaribus vel in axillis defoliatis, solitariis, distincte pedicellatis, circiter 1.5 cm. longis, 4 mm. diametro, acuminatis, nitidis, atro-castaneis, sepalis persistentibus oblongis, obtusis, circiter 5 mm. longis; pedicellis 5–7 mm. longis.

Sumatra, East Coast, Asahan, Loemban Ria, *Rahmat 7687,* Feb.–April, 1935; local name *kajoe si haras.* A species characterized by its rather small chartaceous or subchartaceous, distantly but distinctly nerved, very sparingly glandular leaves, and especially by the tips of the ultimate veinlets being free within the rather lax and distinct ultimate reticulations. It apparently belongs in the group

with *Cratoxylon ligustrinum* (Spach) Blume, but is not closely allied to that species or to other congeners.

Cratoxylon subglaucum Merrill, sp. nov.

Frutex vel arbor parva, glabra, ramis pallidis, teretibus, ramulis ultimis teretibus vel subcompressis, circiter 1 mm. diametro, internodiis 7–18 mm. longis; foliis numerosis, coriaceis, rigidis, ellipticis vel oblongo-ellipticis, basi acutis, apice breviter acute acuminatis, 3–7 cm. longis, 1.5 3 cm. latis, supra pallide olivaceis, nitidis, subtus pallidioribus, glaucis vel subglaucis, haud glandulosis, nervis primariis gracilibus, utrinque 5–7, paullo elevatis, arcuato-anastomosantibus, supra subobsoletis, subtus haud perspicuis, venulis obscuris, intra reticula ultima liberis; petiolo 3–4 mm. longo; floribus ignotis; fructibus axillaribus vel e axillis defoliatis, solitariis, pedicellatis, subcylindraceis, circiter 12 mm. longis, 3 mm. diametro, maturis atro-castaneis, nitidis, rostratis; sepalis oblongis, obtusis, 5 mm. longis.

Sumatra, East Coast, Asahan, near Loemban Ria, *Rahmat 7907*, Feb. April, 1934; local name *kajoe bambon*. This species is apparently allied to the preceding one, but has smaller, less prominently acuminate, stiff, coriaceous, eglandular leaves which are much less distinctly veined and which are distinctly glaucous beneath. As in *Cratoxylon acuminatum* Merr., the tips of the ultimate veinlets are free within the lax reticulations.

ARALIACEAE

Trevesia Burckii Boerl., Ann. Jard. Bot. Buitenzorg, 6 : 110, t. 12, f. 1–14. 1887.

Trevesia cheirantha Ridl., Fl. Malay Penin., 1 : 882. 1922.
Trevesia palmata Vis. var. *cheirantha* C. B. Clarke, in Hook. f., Fl. Brit. Ind., 2 : 732. 1879.

Sumatra, East Coast, Asahan, Bandar Poeloeh, *Yates 1649;* Hoeta Bagasan, *Rahmat 6477, 6780*, Sept., 1934 (local name *kajoe attoe toeroet*); Bosar Si Pinggan, *Hamel 1175*, Sept. 2, 1928; Tapianoeli, Padang Si Dimpoean, Padang Lawas, *Rahmat 4765, 5048*, July, 1933 (local names *kajoe boerle laoet, kajoe obong bolon*). Malay Peninsula, Borneo, and, *fide* Ridley, Burma. The Sumatran form, like that of Borneo, has much larger leaf lobes than Ridley indicates

for the Malay Peninsula form. By error he describes the leaves as 0.2 to 0.8 inch across.

Schefflera quadripetala Merrill, sp. nov. § *Euschefflera, Heptapleurum.*

Frutex ut videtur scandens, inflorescentiis perspicue breviter pallide stellato-pubescentibus, ramis teretibus, ramulis ultimis glabris, 3–4 mm. diametro, laevibus vel longitudinaliter sulcatis; foliis palmatim 3–5-foliolatis, petiolo glabro, 5–10 cm. longo, petiolulis 7–30 mm. longis, glabris; foliolis coriaceis, utrinque glabris, siccitate pallidis, supra nitidis, subtus paullo pallidioribus, lanceolatis vel oblongo-lanceolatis vel oblongo-ellipticis, integerrimis, 5–15 cm. longis, 2–4 cm. latis, graciliter caudato-acuminatis, basi acutis, obscure subtriplinerviis, nervis primariis utrinque 5–7, adscendentibus, haud perspicuis, obscure arcuato-anastomosantibus; inflorescentiis terminalibus, junioribus dense, vetustioribus plus minusve consperse breviter pallide stellato-pubescentibus, haud pedunculatis, ramis primariis 3–8, fasciculatis vel umbellatis, 15–25 cm. longis, basi bracteatis, bracteis ovatis vel lanceolatis, coriaceis, acuminatis, 1–2 cm. longis, persistentibus, pallidis, junioribus stellato-pubescentibus glabrescentibus; floribus 4-, raro 5-meris, umbellatis vel alabastris subcapitato-umbellatis, umbellis in ramis primariis racemose dispositis, 10–20-floris, pedunculis gracilibus, stellato-pubescentibus, 5–10 mm. longis, bracteis lanceolatis, acuminatis, 2–3 mm. longis; alabastris breviter pedicellatis, pedicellis dense stellato-pubescentibus, sub anthesin usque ad 4 mm. longis; calycibus obconicis, haud sulcatis, dense pallide breviter stellato-pubescentibus, circiter 1 mm. longis latisque, petalis 4, rariter 5, oblongo-ovatis, acutis, 2 mm. longis, extus stellato-pubescentibus; filamentis glabris, 2.5 mm. longis; ovario 4–5 loculari.

Sumatra, East Coast, Asahan, near Loemban Ria, *Rahmat 7735, 7964, 8048* (type), *8713*, Feb.–April, 1934; local names *kajoe obang, obang gala, kajoe obang lampoeng.* A species characterized by its stellate-pubescent inflorescences, otherwise glabrous, the 3 to 8 primary inflorescence branches forming a terminal sessile fascicle or umbel, each branch a simple raceme of 25 to 30 or more shortly peduncled umbels, the inflorescences about as long as the leaves, and each branch subtended by a thick, coriaceous, ultimately glabrous, pale, persistent bract. Another unusual characteristic for this genus is that the flowers are usually 4-, rarely 5-merous.

LOGANIACEAE

CYNOCTONUM PANICULATUM (Wall.) B. L. Rob., Proc. Am. Acad. Arts and Sci., 45 : 396. 1910 (Contrib. Gray Herb., 38 : 396).

Mitreola paniculata Wall., List, No. 4349. 1830, *nomen nudum;* G. Don., Gen. Hist., 4 : 171. 1838; A. DC., Prodr., 9 : 9. 1845; Hook., Ic., 9 : t. 828. 1851; Camerloh., Bull. Jard. Bot. Buitenzorg, III, 5 : 298. 1933.

Mitreola oldenlandioides Wall., List, No. 4350. 1830, *nomen nudum;* A. DC., Prodr., 9 : 9. 1845; Hook., Ic., 9 : t. 827. 1851; Benth., Journ. Linn. Soc. Bot., 1 : 91. 1857; Dop, in Lecomte, Fl. Gén. Indo-Chine, 4 : 155, f. 20, 1–2. 1912; Ridl., Fl. Malay Penin., 2 : 413. 1923.

Cynoctonum Mitreola Britt. var. *campylocarpum* Hochr. et var. *orthocarpum* Hochr., Bull. N. Y. Bot. Gard., 6 : 284. 1910.

Cynoctonum oldenlandioides B. L. Rob., Proc. Am. Acad. Arts and Sci., 45 : 396. 1910 (Contrib. Gray Herb., 38 : 396).

Mitreola petiolata sensu Merr., Philip. Journ. Sci., 11 : Bot., 307. 1916; Enum. Philip. Fl. Pl., 3 : 311. 1923, *non* Torr. & Gray.

SUMATRA, East Coast, Loeboehan Batoe, Kota Pinang, Langga Pajoeng, on the Soengei Kanan (topographic sheet 41), *Rahmat 3658*, March, 1933. India to Burma and Indochina through Malaysia to the Caroline Islands and tropical Australia. Camerloher cites numerous collections from Java, Bali, the Kangean Archipelago, and New Guinea. It is rare and very local in the Philippines; Robinson collected it in Amboina.

Hochreutiner proposed two new varietal names under the American *Cynoctonum Mitreola* (Linn.) Britt. for the Old World forms which other authors considered *Mitreola paniculata* Wall. and *M. oldenlandioides* Wall. Admittedly the Indo-Malaysian forms are very similar to certain Brazilian forms of the Linnaean species, but since the North American forms are distinctly different I do not feel that this reduction should be accepted. In accepting the specific name *paniculata* instead of *oldenlandioides* for the Old World species I am merely following G. Don, who selected the former name when he first combined the two Old World species.

Mitreola is the generally accepted name for this small genus of the Loganiaceae, with a few representatives in the warmer parts of both hemispheres. Linnaeus proposed it in 1737 in the first edition of the *Genera Plantarum* (p. 377), but in the 1754 edition reduced it to Oldenlandia; in 1753 he had erroneously placed its type species under Ophiorrhiza as *O. Mitreola* Linn. R. Brown in 1810 seems to have been the first to reinstate Mitreola, but in 1791 J. F. Gmelin had re-

named it Cynoctonum. This name has been adopted by various American botanists, including the late Dr. B. L. Robinson, who, although regretting the change, stated correctly that under the international code Cynoctonum Gmelin would have to stand.

Fagraea Rahmatii, sp. nov.

Arbor glabra, ramis teretibus, ultimis circiter 3 mm. diametro; foliis coriaceis, siccitate utrinque verruculosis, fragilibus, oblongo-ellipticis vel oblongo-ovatis, 6-11 cm. longis, 2.5-6 cm. latis, breviter acute acuminatis, basi acutis, nervis primariis utrinque 5–8, gracilibus, obscuris, petiolo circiter 1 cm. longo; inflorescentiis terminalibus, paucifloris, brevibus, breviter pedunculatis; floribus ut videtur albidis, 7 cm. longis, pedicellis sursum incrassatis, 8–12 mm. longis, bracteis ovatis, acuminatis, circiter 3 mm. longis, bracteolis paullo minoribus; calycis tubo sursum ampliato, circiter 7 mm. longo, lobis ovatis, obtusis, tubum subaequantibus; corollae tubo circiter 4 cm. longo, deorsum vix 3 mm. diametro, sursum ampliato, lobis ellipticis, rotundatis, circiter 2.5 cm. longis.

Sumatra, East Coast, Aer Perlajoean, near Rantau Parapat, Bila, *Rahmat 2290*, May 24, 1932. In the group of *F. obovata* Wall.; characterized by its relatively small calyces, slender corolla tubes, and sharply short-acuminate leaves.

SCROPHULARIACEAE

Limnophila laxa Benth., in DC., Prodr., 10 : 388. 1846; Ridl., Fl. Malay Penin., 2 : 478. 1923.

Sumatra, East Coast and Tapianoeli, numerous localities, *Yates 1364*, *Rahmat 1820*, *2318*, *2380*, *2554*, *2728*, *2811*, *2901*, *4288*, *4395*, *5023*, May, 1932 — July, 1933. Ceylon to Tenasserim, Burma, and the Malay Peninsula.

Limnophila fragrans (Forst. f.) Seem., Fl. Vit., 180. 1866.

Ruellia fragrans Forst. f., DC., Prodr., 44. 1786.
Limnophila serrata Gaudich., Bot. Freyc. Voy., 448, t. 57, f. 2. 1826.

Sumatra, Tapianoeli, Padang Si Dimpoean, Padang Lawas, *Rahmat 4443*, *4573*, May June, 1933. Southern Asia through Malaysia to tropical Australia, eastward through Polynesia to Tahiti.

Lindernia elata (Benth.) Wettst., in Engl. and Prantl, Nat. Pflanzenfam., 4(3b): 79. 1891; Bonati, in Lecomte, Fl. Gén. Indo-Chine, 4: 418. 1927.

Tittmannia elata Benth., in Wall., List., No. 3944. 1830, *nomen.*
Vandellia elata Benth., Scroph. Ind., 36. 1835; DC., Prodr., 10: 414. 1846; Hook. f., Fl. Brit. Ind., 4: 280. 1884; Ridl., Fl. Malay Penin., 2: 481. 1923.

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Langga Pajoeng, and Goenoeng Si Papan, *Rahmat 3439, 3445, 3762*, March–April, 1933. Burma to Indochina and the Malay Peninsula. This species seems to be closely allied to *Lindernia urticifolia* (Hance) Bonati, type from Kwangtung Province, China.

Lindernia obtusa (Blume) Koord., Exkursionsfl. Java, 3: 178. 1912.

Torenia obtusa Blume, Bijdr., 754. 1826; Benth., in DC., Prodr., 10: 412. 1846.
Vandellia obtusa Miq., Fl. Ind. Bat., 2: 691. 1857.

Sumatra, East Coast, Bila, Goenoeng Soeasah, near Rantau Parapat, *Rahmat 2350*, May, 1932. Java. This is generally considered to be of more or less doubtful status (Bentham, Koorders). It seems to me to be rather close to *Lindernia angustifolia* Wettst., and is perhaps a short-leaved form of that species.

Lindernia viscosa (Hornem.) Merr., Enum. Philip. Fl. Pl., 3: 439. 1923; Alst., in Trimen, Fl. Ceyl., 6 (Suppl.): 213. 1931.

Gratiola viscosa Hornem., Enum. Pl. Hort. Hafn., 19. 1807.
Hornemannia viscosa Willd., Enum., 654. 1809.
Vandellia hirsuta Ham., ex Benth., Scroph. Ind., 36. 1835; Ridl., Fl. Malay Penin., 2: 480. 1923.
Tittmannia viscosa Rchb., Ic. Exot., 1: 26, t. 38. 1824.
Hornemannia prostrata Jacq. f., Ecl., 2: 9 (*in syn.*), t. 150. 1844.
Vandellia viscosa Merr., Philip. Journ. Sci., 7: Bot., 246. 1912.
Lindernia hirsuta Wettst., in Engl. and Prantl, Nat. Pflanzenfam., 4(3b): 79. 1891.

Sumatra, East Coast, Bila, Sigamata, near Rantau Parapat, *Rahmat 2838, 3161*, June July, 1932; Tapianoeli, Padang Si Dimpoean, Padang Lawas, *Rahmat 5002*, July, 1933; Laboehan Batoe, Kota Pinang, Goenoeng Si Papan, *Rahmat 3757*, April, 1933. India to southern China southward to Java and the Philippines. When I published the accepted binomial in 1923 I inadvertently gave Willdenow as the author of the original name; when Alston republished it independently in 1931 he based his new name on *Tittmannia vis-*

cosa Rchb. (1824); the accepted specific name dates from Hornemann (1807).

PICRIA FEL-TERRAE Lour., Fl. Cochinch., 393. 1790; Merr. Trans. Am. Philos. Soc., II, 24 (2) : 352. 1935.

Caranga amara Vahl, Enum., 1 : 100. 1804.
Curanga amara Juss., Ann. Mus. Hist. Nat. Paris, 9 : 320. 1807; Ridl., Fl. Malay Penin., 2 : 484. 1923.
Curanga fel-terrae Merr., Interpret. Herb. Amb., 467. 1917.

SUMATRA, East Coast, Asahan, *Hamel 1031*, Aug. 23, 1928; Laboehan Batoe, Kota Padang, *Rahmat 3657*, March, 1933; Tapianoeli, Padang Si Dimpoean, Padang Lawas, *Rahmat 4649*, June, 1933; local name *pogoe tano*. India to Indochina and Hainan southward through Malaysia to the Moluccas.

RAZUMOVIA TRANQUEBARICA Spreng., Fl. Hal. Mant., 45. 1807; Britten, Journ. Bot., 39 : 69. 1901.

Centranthera humifusa Wall., List, No. 3883. 1830, *nomen nudum;* Benth., Scroph. Ind., 50. 1835; DC., Prodr., 10 : 535. 1846.

SUMATRA, East Coast, Laboehan Batoe, Kota Pinang, Saboengan, on the Soengei Kanan, *Rahmat 3717*, March–April, 1933. India and Ceylon to Indochina and southeastern China, the Malay Peninsula, Java, and Borneo.

The genus Razumovia Sprengel (1807) replaces Centranthera R. Brown (1810), as indicated by Britten in 1901. Other synonyms of this species are *Torenia lepidota* Roth (1821) and *Razumovia lepidota* Alston (1931).

RUBIACEAE

GAERTNERA ACUMINATA Benth., Journ. Linn. Soc. Bot., 1 : 112. 1856; Ridl., Journ. Straits Branch Roy. As. Soc., 79 : 98. 1918; Fl. Malay Penin., 2 : 427. 1923.

SUMATRA, Tapianoeli, Padang Si Dimpoean, Padang Lawas, Poelo Liman, *Rahmat 5210*, Aug., 1933; East Coast, Asahan, Bandar Poeloeh, *Yates 1767;* Tandjong Pasir, *Yates 2550*. Malay Peninsula.

I do not know the possible relationships of *G. Junghuhniana* Miq. (1857) and *G. Zollingeriana* Miq. (1857) to the two species here recorded. *G. oxyphylla* Benth. has been recorded from Sumatra, but Ridley places it in varietal rank as *G. acuminata* Benth. var. *oxyphylla* Ridl.

Gaertnera borneensis Valeton, in Winkler, Bot. Jahrb., 44 : 568. 1910.

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Langga Pajoeng, Si Mandi Angin, and Saboengan, *Rahmat 3296, 3727, 3993, 4102*, April May, 1933. This is one of the Malayan forms that have been referred to *Gaertnera vaginans* (DC.) Merr. (*G. Koenigii* Wight), but Ridley states that the latter is endemic to Ceylon. Valeton considered *G. borneensis* to be the Bornean representative of *G. Koenigii* Wight. It seems doubtful to me if *G. brevistylis* Ridl., *Kew Bull.*, 124. 1934, type from Sandakan, Borneo, and Balambangan, is really distinct from *G. borneensis*.

Ixora neriifolia Jack, Malay Miscel., 2 (7) : 82. 1822; Hook., Comp. Bot. Mag., 1 : 254. 1835 (reprinted description).

Pavetta salicifolia Blume, Bijdr., 951. 1826.
Ixora salicifolia DC., Prodr., 4 : 487. 1830.
Ixora fulgens Roxb. var. *salicifolia* Koord. & Valeton, Meded. Lands Plant., 59 : 158. 1902 (Bijdr. Boomsoort. Java, 8 : 158); Koord., Atlas Baumart. Java, 3 : t. 551. 1915.

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Si Mandi Angin, *Rahmat 4148*, April, 1933; Bila, Rantau Parapat, *Rahmat 2072*, March–May, 1932; Asahan, Bandar Poehloch, *Yates 1644;* Hoeta Padang, *Krukoff s. n.*, Nov., 1932. Malay Peninsula, Java, Borneo, and the Philippines. Jack's species, its type from the west coast of Sumatra, seems clearly the same as Blume's described four years later from a Javan type.

Lasianthus Lowianus King & Gamble, Journ. As. Soc. Bengal, 74 (2) : 871. 1909 (Mater. Fl. Malay. Penin., 4 : 1081); Ridl., Fl. Malay Penin., 2 : 167. 1923.

Lasianthus lucidus King & Gamble, *op. cit.*, 73 (2) : 132. 1904 (Mater. Fl. Malay. Penin., 4 : 206), *non* Blume.

Sumatra, East Coast, Asahan, Loemboen Ria and Hoeta Bagasan, *Rahmat 6712, 6982, 7775, 7830*, Sept., 1934 — Feb., 1935 (local names *kajoe lamlam, kajoe si baoe te, kajoe si lamlam baoe*); Masihi Forest Reserve, *Krukoff 4077*, Oct. 15, 1932; near Bangoen Dolok, *Hamel 1185*, Sept. 2, 1928. Malay Peninsula.

Lucinaea membranacea King, Journ. As. Soc. Bengal, 72 (2) : 178. 1903 (Mater. Fl. Malay. Penin., 4 : 68); Ridl., Fl. Malay Penin., 2 : 56. 1923.

Sumatra, East Coast, Damoeli, Koealoe, *Rahmat 1517*, Oct., 1928; near Aek Sordang, Loendoet Concession, *Bartlett 7618, 7650*, May, 1927; near Bilah Pertama (Parbasiran), *Rahmat 139*, March, 1928; Asahan, Loemboen Ria, *Rahmat 7423, 7966*, Feb.–April, 1931; local name *sarindan*. Ridley has already recorded this species from the Mentawei Islands, off the west coast of Sumatra. Except for the description of *L. sumatrana* Koord. & Val. (1911) as an erect shrub, I should, from the diagnosis, be inclined to place it as a synonym of King's species.

Morinda elliptica (King) Ridl., Journ. Straits Branch Roy. As. Soc., 79 : 86. 1918; Fl. Malay Penin., 2 : 118. 1923.

Morinda citrifolia Linn. var. *elliptica* King, Journ. As. Soc. Bengal, 73 (2) : 87. 1904 (Mater. Fl. Malay. Penin., 4 : 160).

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Si Mandi Angin, *Rahmat 4052*, April-May, 1923; local name *kajoe tammoesoeh tombak*. Malay Peninsula; its wider distribution uncertain because of confusion with *M. citrifolia* Linn.

Oldenlandia tetrangularis (Korth.), comb. nov.

Diplophragma tetrangulare Korth., Nederl. Kruidk. Arch., 2 (2) : 149. 1851.
Hedyotis tetrangularis Walp., Ann., 2 : 769. 1851; Valeton, Bot. Jahrb., 44 : 543. 1910 (amplified description).
Hedyotis quadrangularis Miq., Fl. Ind. Bat., 2 : 180. 1857.
Hedyotis Parryi Hance, Ann. Sci. Nat., IV Bot., 18 : 221. 1862.
Oldenlandia Parryi O. Ktze. Rev. Gen. Pl., 1 : 292. 1891.
Oldenlandia quadrangularis O. Ktze., *l. c.*

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Langga Pajong, and Si Mandi Angin, *Rahmat 3317, 3499, 3540, 3720, 4113, 4173*, March–May, 1933. Borneo, southeastern China. Valeton gave an excellent greatly amplified description of Korthals' species in 1912, and I have personally examined Korthals' type at Leiden. I note no characters by which *Hedyotis Parryi* Hance can be distinguished.

Pomazota rivularis Henderson, Gard. Bull. Str. Settl., 4 : 211, f. 1–3. 1929.

Sumatra, East Coast, Asahan, near Hoeta Bagasan, *Rahmat 6748, 6800*, Sept., 1934 — Feb., 1935; local name *doehoet batoe*. Malay Peninsula. The first representative of the genus to be recorded from Sumatra; two species in the Malay Peninsula; one in Borneo.

Randia cochinchinensis (Lour.) Merr., Trans. Am. Philos. Soc., II, 24 (2) : 365. 1935.

Aidia cochinchinensis Lour., Fl. Cochinch., 143. 1790; Moore, Journ. Bot., 63 : 250. 1925.
Webera oppositifolia Roxb., Fl. Ind., 2 : 535. 1824; ed. 2, 1 : 698. 1832.
Stylocoryna racemosa Cav., Ic., 4 : 46, t. 368. 1797.
Randia racemosa F.-Vill., Novis. App. Fl. Philip., 108. 1880, *non* Roxb.
Randia densiflora Benth., Fl. Hongk., 155. 1861.
Randia oppositiflora K. Schum., Bot. Tidsskr., 24 : 332. 1902.
Randia oppositifolia Koord., Exkursionsfl. Java, 3 : 257. 1912.

There are a number of Sumatran collections of this common and widely distributed species, including *Yates 1340, 1998,* and *Rahmat 3968, 4048.* I have accepted Loureiro's specific name, after having examined his type, for this much-named species; there are probably in excess of twenty to twenty-five synonyms. Attention is called to the fact that *Webera "oppositiflora"* Roxb., on which *Randia oppositiflora* K. Schum. was ostensibly based, does not exist; doubtless Schumann intended *W. oppositifolia* Roxb.

Randia fragrantissima Ridl., Journ. Straits Branch Roy. As. Soc., 50 : 115. 1908; Fl. Malay Penin., 2 : 75. 1923.

Sumatra, East Coast, Batoe Barah, between Tanah Datar and Tandjoeng Tiram, *Bartlett 7156,* April 10, 1926, flowers fragrant, white, turning yellow; Asahan, Masihi Forest Reserve, *Krukoff 4168,* Oct. 26, 1932, borders of clearings in forests. Malay Peninsula.

Streblosa Wallichii, nom. nov.

Psychotria microcarpa Wall., List, No. 8344. 1848, *nomen, non* Muell.-Arg. 1881.
Psychotria tortilis sensu Hook. f., Fl. Brit. Ind., 3 : 169. 1880, *non* Blume.
Streblosa microcarpa Ridl., Fl. Malay Penin., 2 : 148. 1923.

Sumatra, East Coast, Asahan, Silo Maradja, *Bartlett 8686,* June, 1927; Tapianoeli, Padang Si Dimpoean, Padang Lawas, along the Aek Roppak, *Rahmat 4675,* June, 1933. Malay Peninsula, Penang.

I agree with Ridley that *Psychotria microcarpa* Wall. is not the same as the Javan *Streblosa tortilis* (Blume) Korth. (*Psychotria tortilis* Blume), but Wallich's specific name is an invalid one in Psychotria and hence in Streblosa. My concept of Wallich's species is largely based on *Lobb 286,* labeled as from Singapore, but Ridley states that it was probably from Penang. In this the leaves are black-punctate above and nearly glabrous beneath.

Streblosa puberula Merrill, sp. nov.

Suffrutex erectus, 20–60 cm. altus, simplex vel rariter ramosus, caulibus deorsum 4–8 mm. diametro, glabris, novellis breviter pubescentibus vel puberulis, internodiis 2–7 cm. longis; foliis ovatis vel elliptico-ovatis, breviter acute vel abrupte acuminatis, basi acutis, 8–13 cm. longis, 3–7 cm. latis, chartaceis vel submembranaceis, siccitate supra glabris, pallide olivaceis, dense et plerumque albido-puncticulatis, subtus pallidioribus, ad costam nervosque breviter subcinereo-puberulis, nervis primariis utrinque 10 14, perspicuis; stipulis bifidis, glabris, 6–8 mm. longis, lobis anguste lanceolatis, acuminatis; petiolo 1–4 cm. longo; inflorescentiis axillaribus, breviter subcinereo-pubescentibus, sessilibus vel brevissime pedunculatis, 1.5–3 cm. longis, multifloris, floribus confertis; fructibus numerosis, circiter 1.5 mm. longis et 2 mm. latis, consperse pubescentibus, obscure vel vix sulcatis.

Sumatra, Tapianoeli, Padang Si Dimpoean, Padang Lawas, Si Harehare Djaë (topographic sheet 41, northwest corner), *Rahmat 5000* (type), July, 1933; also from the same subdivision, Aek Roppak, near Hoeta Imbaroe and Sopsopan on Aek Si Olip (all on topographic sheet 41, northwest corner), *Rahmat 4636*, *4771*, *5101*, June–July, 1933. *Rahmat 6543* from Hoeta Bagasan, Asahan, Sept., 1934 — Feb., 1935, local name *doehoet tombak*, apparently represents the same species. Allied to *Streblosa microcarpa* (Wall.) Ridl. (= *Streblosa Wallichii* Merr.), but differs in numerous characters, notably in its indumentum and in its leaves being usually rather densely white-puncticulate on the upper surface and puberulent on the midrib, lateral nerves and reticulations beneath.

Canthium longistylum Merrill, sp. nov.

Ut videtur arbor parva, inermis, ramis teretibus, glabris, internodiis 5–8 cm. longis, ramulis ultimis glabris, 2 mm. diametro; foliis subcoriaceis, utrinque nitidis siccitate viridibus vel pallide olivaceo-viridibus, supra glabris, subtus ad costam nervosque pallide breviter molliter patule pubescentibus, ovatis vel ovato-ellipticis, 8–15 cm. longis, 4 8 cm. latis, basi acutis, apice perspicue obtuseque acuminatis, nervis primariis utrinque 5–6, subadscendentibus, perspicuis, elevatis, anastomosantibus, axillis haud glandulosis vel barbatis; petiolo circiter 1 cm. longo, puberulo; stipulis circiter 5 mm. longis, puberulis,

ovatis vel ovato-oblongis, obtusis vel acuminatis, deciduis; cymis axillaribus, breviter pedunculatis, multifloris, dichotome ramosis, breviter pubescentibus, 4–6 cm. longis; pedunculo crasso, 5–9 mm. longo; floribus numerosis, in ramulis ultimis plus minusve confertis, pedicellatis, albidis, 5-meris; pedicellis pubescentibus, 2–3 mm. longis; calycibus pubescentibus, circiter 1 mm. longis, breviter dentatis; corollae tubo extus glabro, intus villoso, circiter 2 mm. longo, lobis oblongo-ovatis, reflexis, acutis, quam tubo paullo brevioribus; stylis glabris, gracilibus, longe (ca. 4 mm.) exsertis.

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Si Mandi Angin, Saboengan, and Langga Pajoeng, on the Soengei Kanan (topographic sheet 41), *Rahmat 3601* (type), *3629*, *3793*, *3994*, *4038*, March–May, 1933; local name *kajoe andjedjer*. A species apparently allied to *Canthium Korthalsianum* Miq., type from western Sumatra, but with larger leaves, longer, very many-flowered cymes, and pubescent calyces.

Gardenia dolichantha Merrill, sp. nov.

Arbor, ramis glabris, ramulis ultimis circiter 4 mm. diametro, novellis plus minusve resinosis, internodiis brevibus, 5–10 mm. longis; foliis coriaceis, oblongo-obovatis, 9–20 cm. longis, 4–9 cm. latis, supra olivaceis, nitidis, glabris, subtus pallidioribus, consperse pubescentibus, apice obtusis vel brevissime obtuseque acuminatis, basi acutis, nervis primariis utrinque 10–15, subtus elevatis, perspicuis; petiolo crasso, leviter pubescenti, 5–10 mm. longo; stipulis cylindraceis, 5–10 mm. longis, obscure bilobatis vel subtruncatis, consperse adpresseque pubescentibus; floribus terminalibus, solitariis, circiter 14 cm. longis, subsessilibus vel brevissime crasseque pedicellatis; calycis tubo 6–8 cm. longo, cylindraceo, deorsum circiter 1 cm. diametro, obscure pubescenti, glabrescenti, coriaceo, longitudinaliter reticulato-venoso, sursum ampliato et circiter 2 cm. diametro, truncato; corollae tubo cylindraceo, circiter 3 mm. diametro, quam calyce saltem duplo longiore, subglabro vel obscure consperseque pubescenti, lobis circiter 8, patulis, obovatis, rotundatis, 4.5–5.5 cm. longis.

Sumatra, East Coast, Laboehan Batoe, Kota Pinang, Goenoeng Si Papan, Kaloebi Concession (topographic sheet 41, southeast quarter), *Rahmat 3925*, April 7–14, 1933; local name *kajoe salin bodat*. A remarkable species because of its very long flowers and its

greatly elongated, truncate calyx tubes that flare somewhat at the apex. It is allied to *Gardenia speciosa* Hook. f., based upon *Lobb 483,* which is labeled as coming from Singapore but which probably came from elsewhere in the Malayan region. In *G. speciosa* the calyx tube is but 2 to 4 cm. long, whereas in *G. dolichantha* it is 6 to 8 cm. long.

Gynochthodes pubifolia Merrill, sp. nov.

Frutex scandens, subtus foliis consperse breviterque pubescentibus vel puberulis, ramis ramulisque teretibus, glabris, ramulis ultimis circiter 1 mm. diametro; foliis ellipticis vel minoribus lanceolatis, basi acutis, chartaceis, siccitate subatro-olivaceis, nervis primariis utrinque 7–8, subtus perspicuis, elevatis, axillis haud glandulosis, foliis majoribus 10–14 cm. longis, 7–8 cm. latis, apice abrupte perspicue acuminatis, minoribus 6–8 cm. longis, 2–2.5 cm. latis, apice subcaudato-acuminatis; petiolo usque ad 1 cm. longo, glabro; floribus axillaribus, solitariis, sessilibus, calycibus glabris, truncatis, 1.5 mm. longis.

Sumatra, East Coast, Bila, near Rantau Parapat, *Rahmat 1965,* March–May, 1932. Striking characters of this species are its heteromorphous leaves, the large ones in general elliptic and abruptly acuminate, the smaller ones lanceolate and gradually narrowed to the subcaudate-acuminate apex, all more or less pubescent or puberulent beneath. Its indumentum is suggestive of *Gynochthodes puberula* Craib, of Siam, but otherwise it does not conform with Craib's description, especially in its solitary sessile flowers.

Hedyotis sumatrana Merrill, sp. nov.

Suffruticosa, erecta, ramosa, 30–40 cm. alta, caulibus deorsum lignosis, teretibus vel obscure 4-angulatis, ramis distincte 4-angulatis vel sulcatis, consperse breviter hirsutis, ramulis ultimis 1 mm. diametro; foliis oblongis vel oblongo-ellipticis, siccitate subviridibus, chartaceis vel subcoriaceis, 2–5.5 cm. longis, 1–1.5 cm. latis, plerumque acutis, basi acutis, breviter petiolatis, supra consperse breviter subscabrido-hirsutis, subtus plus minusve hirsutis, nervis primariis utrinque 4 vel 5, gracilibus, haud perspicuis, curvato-adscendentibus; petiolo breviter hirsuto, 3–5 mm. longo; stipulis ovatis vel lanceolatis, usque ad 4 mm. longis, breviter hirsutis, obscure laciniatis, inflorescentiis axillaribus terminalibusque, globosis, dense

multifloris, sessilibus, sub fructu 1 2 cm. diametro; floribus 4-meris, albidis, sessilibus vel breviter pedicellatis, calycis tubo circiter 2 mm. longo, extus consperse hirsuto, lobis tubo aequantibus, oblongis vel lanceolatis, extus ciliato-hirsutis, intus glabris, acutis vel acuminatis; corolla parva, circiter 3 mm. longa, tubo 2 mm. longo, extus glabro, lobis ovatis, obtusis, extus leviter hirsutis; capsulis subellipsoideis, consperse hirsutis, 2.5 3 mm. longis, septicide dehiscentibus, lobis persistentibus paullo accrescentibus, patulis vel recurvatis; seminibus paucis, nigris, 0.5 mm. longis, angulatis.

Sumatra, East Coast, Asahan, near Loemban Ria, *Rahmat 7594, 7728* (type), Feb. April, 1934; local name *doehoet soebang*. Also represented by *Bartlett 7530* from the Toba trail, north of the Asahan River, between Toetoepan and Si Makkoek, Tapianoeli, April, 1927. This species in habit and general appearance resembles *Hedyotis uncinella* Hance (*H. cephalophora* R. Br.), differing radically in its indumentum. The capsules are usually 8-seeded, 4 seeds in each cell. From Ridley's description I judge *Hedyotis stelligera* Ridl. to be allied. The type of the latter is from sandy heaths, Setul, Malay Peninsula.

Mycetia myrioneura Merrill, sp. nov.

Frutex erectus, plus minusve crispatule pubescens, ramis teretibus, glaberrimis, pallidis, nitidis, novellis leviter hirsutis; foliis membranaceis, late lanceolatis, 18-30 cm. longis, 4-8 cm. latis, supra olivaceis, consperse pubescentibus glabrescentibus, subtus concoloribus vel paullo pallidioribus, praesertim ad costam nervosque perspicue crispatulo-pubescentibus, graciliter acuminatis, deorsum longe angustatis, cuneatis vel decurrenti-acuminatis, nervis primariis utrinque 30 35, gracilibus, inter se 4 8 mm. distantibus, patulis vel patule curvatis, circiter ad marginem arcuato- vel curvato-anastomosantibus, gracilibus, subtus distinctis; petiolo 2-7 cm. longo, subglabro vel plus minusve pubescenti; stipulis ovatis, acuminatis, circiter 5 mm. longis; paniculis terminalibus, pedunculatis (pedunculo 1.5–2 cm. longo), laxis, multifloris, sub fructu 8-14 cm. latis, partibus floriferis fructiferisque 4 8 cm. longis; floribus parvis, calycibus glabris, lobis ovatis, 1 mm. longis, lobulis paucis, claviformibus vel subcapitatis, 0.5 mm. longis; corollae tubo cylindraceo, circiter 2 mm. longo, lobis circiter 0.5 mm. longis, extus plus minusve hirsutis;

fructibus depresso-globosis, glabris, circiter 4 mm. longis, 5 mm. diametro, pedicellis 5–7 mm. longis; bracteolis subreniformibus, circiter 1.5 mm. diametro, subintegris vel lobulis paucis subclavellatis vel subcapitatis ferentibus.

Sumatra, East Coast, Asahan, near Hoeta Bagasan, *Rahmat 6544, 7273* (type), Sept., 1934 — Feb., 1935; local name *kajoe martoemboes*. *M. myrioneura* is strongly characterized by its elongated, many-nerved leaves.

Psychotria castaneopila Merrill, sp. nov. § Grumilea.

Frutex erectus, partibus junioribus, inflorescentiis et foliis subtus breviter castaneo-pubescentibus, ramulis ultimis circiter 5 mm. diametro; foliis magnis, firmiter chartaceis, obovatis vel late oblongo-obovatis, 20–30 cm. longis, 11–15 cm. latis, breviter acuminatis vel acutis, basi acutis, supra glaberrimis, pallide olivaceo-viridibus, subtus plus minusve brunneis, praesertim ad costam nervosque perspicue breviter castaneo-pubescentibus; nervis primariis utrinque circiter 15, subtus valde perspicuis, elevatis, plus minusve curvatis, marginem attingentibus vel superioribus juxta marginem curvato-anastomosantibus, secundariis distinctis, subparallelis, cum reticulis plus minusve elevatis, castaneo-pubescentibus; petiolo crasso, castaneo-pubescenti, 2–3 cm. longo; infructescentiis castaneo-pubescentibus, sessilibus vel breviter pedunculatis, subpyramidatis, circiter 7 cm. longis et 8 cm. latis, paniculatis, ramis primariis paucis, 2–4 cm. longis, superioribus brevioribus; fructibus ovoideis vel subellipsoideis, glabris vel obscure pubescentibus, circiter 9 mm. longis, pedicellatis, longitudinaliter 8–10-carinatis, leviter sulcatis, calycis lobis 5 coronato; seminibus plano-convexis, dorso plerumque leviter 4-carinatis, albumine vix vel obscure ruminato.

Sumatra, East Coast, Asahan, near Hoeta Bagasan, *Rahmat 6719* (type), Sept., 1933 — Feb., 1935; local name *kajoe toemboes-toemboes*. No. *6963* from the same locality is probably the same; local name *kajoe itom*. Among the erect, more or less pubescent shrubs with ruminate albumen and 5-merous flowers, this species is characterized by its large, prominently nerved leaves which are castaneous-pubescent with short hairs on the midribs, lateral nerves, secondary nerves and reticulations beneath. The albumen is only very slightly ruminate, so slightly so that the species might with almost equal propriety

be placed among those with smooth albumen. The numerous intergrades between nonruminate and ruminate albumen, and the fact that these intergrades are found in the two habit groups, erect and scandent shrubs, and in these two subdivisions also among the pubescent and the glabrous species, in my judgment invalidates the genus Grumilea, which was separated from Psychotria solely because its seeds had ruminate instead of smooth albumen.

Psychotria cylindrostipula Merrill, sp. nov.

Frutex scandens, floribus obscure cinereo-puberulis exceptis glaber, ramis ramulisque teretibus, ultimis circiter 2 mm. diametro, internodiis 5 9 cm. longis, interdum rhizophoraceis; foliis subcoriaceis, oblongis vel anguste oblongo-ellipticis, 10–13 cm. longis, 3–5 cm. latis, olivaceis vel brunneis, nitidis, laevibus, breviter obtuse vel acute acuminatis, basi acutis, nervis primariis utrinque 7 vel 8, gracilibus, haud perspicuis, inconspicue vel vix anastomosantibus, reticulis obsoletis, petiolis 1–1.5 cm. longis; stipulis cylindraceis, circiter 3 mm. longis crassisque, truncatis; inflorescentiis pedunculatis, simplex vel depauperater ramosis, alabastris immaturis puberulis, sessilibus, in capitulis 1 vel 3 densis 5–8 mm. diametro dispositis, pedunculo sub fructu 2.5 cm. longo; fructibus subellipsoideis, circiter 5 mm. longis, leviter longitudinaliter carinatis vel sulcatis, breviter pedicellatus, subumbellatim dispositis; seminibus plano-convexis, dorso plerumque 4-carinato, albumine haud vel obscurissime ruminato.

Sumatra, East Coast, Asahan, near Loemban Ria, *Rahmat 7443, 8116* (type), Feb.–April, 1934; *Yates 1901*, Bandar Poeloeh, Asahan (distributed as a species of Tarenna). Among the scandent nearly glabrous species, this one is characterized by its obsolete reticulations and capitate flowers. The young buds are minutely cinereous-puberulent; the plant is otherwise glabrous. Like the broad-leaved erect shrub described above as *Psychotria castaneopila*, the seeds are only very slightly or scarcely ruminate; so little so that it can hardly be placed in the section Grumilea, if it be even possible to retain this section.

Psychotria minutifoveolata Merrill, sp. nov.

Frutex scandens, ramulis, petiolis, inflorescentiis et foliis subtus praesertim ad costam nervosque perspicue sordide pubescentibus,

pilis 1–2 mm. longis, foliis utrinque sub lente minutissime denseque foveolatis, ramulis ultimis vix 1 mm. diametro, internodiis 2–5 cm. longis; foliis chartaceis vel submembranaceis, late oblongis vel oblongo-ovatis vel ovatis, 4–7 cm. longis, 2–4 cm. latis, acutis, obtusis, vel obscure acuminatis, basi rotundatis, supra consperse strigoso-hirsutis, pallide olivaceis, subtus paullo pallidioribus, nervis primariis utrinque 6–8, gracilibus, subtus distinctis, petiolo dense hirsuto, 2–4 mm. longo; stipulis hirsutis; inflorescentiis terminalibus, cymosis, 2–3 cm. longis, usque ad 4 cm. latis, hirsutis, paucifloris, dichotome ramosis; floribus pedicellatis, parvis, calycis tubo breviter hirsuto, lobis oblongis, circiter 1 mm. longis, corollae tubo vix 1 mm. longo, extus breviter hirsuto; fructibus oblongo-ellipsoideis, glabris vel subglabris, circiter 1 cm. longis, longitudinaliter perspicue carinatis sulcatisque, pyrenis plano-convexis, dorso 4-carinatis, albumine aequabili.

Sumatra, East Coast, Asahan, near Hoeta Bagasan, *Rahmat 6577* (type), *6735*, *6810*, Sept., 1934 — Feb., 1935. Also represented by *Rahmat 4520* from Aer Kandis, Rantau Parapat, Bila, May–June, 1932. Among the scandent pubescent species with nonruminate albumen, this species is characterized by its thin leaves, minutely and densely foveolate on both surfaces, the pitting evident under a lens, and by its indumentum.

Urophyllum Rahmatii Merrill, sp. nov.

Arbor parva, ramulis et inflorescentiis et foliis subtus plus minusve molliter villosis, ramis teretibus, glabris, ramulis sulcatis vel compressis, 2 mm. diametro, consperse patule villosis; foliis oblongo-lanceolatis, graciliter caudato-acuminatis, basi late acutis, chartaceis, 10–16 cm. longis, 2.5–4.5 cm. latis, supra glabris, plerumque olivaceis, nitidis, subtus paullo pallidioribus, praesertim ad costam nervosque molliter patule consperse villosis; nervis primariis utrinque 7 vel 8, gracilibus, distinctis, curvato-adscendentibus, vix anastomosantibus sed marginem attingentibus, subtus perspicuis, elevatis; petiolo 7–14 mm. longo, piloso; stipulis lineari-lanceolatis, acuminatis, pilosis, circiter 1.5 cm. longis; inflorescentiis axillaribus, longe pedunculatis, sub fructu 5–8 cm. longis, laxis, ut videtur paucifloris, villosis, pedunculo 3–4 cm. longo; bracteolis linearibus, pilosis, 2–3 mm. longis; fructibus subumbellatim vel depauperate cymosim dis-

positis, pedicellis pilosis, 8–12 mm. longis; fructibus subglobosis vel cupulatis, truncatis, 4–6 mm. longis, consperse pilosis glabrescentibus.

Sumatra, East Coast, Asahan, near Loemban Ria, *Rahmat 6542, 7343* (type), *7758*, Feb.–April, 1934 (local name *kajoe oelam roehoe-roehoe*); *Bartlett 8082*, Soenggapa to Pargambiran, Asahan, May 22, 1927. A species characterized by its indumentum, its long-peduncled few-flowered cymes, and its long-pedicelled fruits, with bracteoles greatly reduced.

Tarenna sumatrensis (Roth) Bremek., Repert. Sp. Nov., 37 : 206. 1934.

Pavetta sumatrensis Roth, Nov. Pl. Sp., 88. 1821.
Wahlenbergia fragrans Blume, Cat. Gew. Buitenzorg, 15. 1823.
Stylocoryna fragrans Blume, Bijdr., 982. 1826; Ridl., Fl. Malay Penin., 2 : 108. 1923.
Ceriscus fragrans Nees, Flora, 8 : 116. 1825.
Webera fragrans Hook. f., Fl. Brit. Ind., 3 : 103. 1880.
Tarenna fragrans Koord. & Valeton, Meded. Lands Plant., 59 : 77. 1902 (Bijdr. Boomsoort. Java, 8 : 77).

Among other Sumatran collections this species is represented by *Yates 1389* and *Rahmat 4427, 4896*. Bremekamp's acceptance of Roth's specific name in 1934 raises an interesting question as to its validity, for Ridley, eight years earlier, *Kew Bull.*, 69. 1926, published *Tarenna sumatrana* (Boerl.) Ridl. based on *Webera sumatrana* Boerl. in Veth, *Mid.-Sumatra*, 4 (2) : 21. 1884. He interpreted Boerlage's species from the description and illustration, but it should be noted that Boerlage describes the ovary cells as 1-ovulate; this, if true, would eliminate the species from Tarenna. Attention is again called to the fact that Stylocoryna Cavanilles is a synonym of Randia, and thus cannot be maintained for the group to which Ridley applied it. Malay Peninsula, Sumatra, Java, Borneo, and Palawan.

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FURTHER NOTES ON THE DESMIDS OF ISLE ROYALE, MICHIGAN

THE GENUS COSMARIUM

GERALD W. PRESCOTT

IN A previous paper (4) the writer made an introductory report on the desmids of Isle Royale. Since then continued examinations of the collections [1] have brought the list of species to approximate completeness. However, some collections are so rich in variety and number of individuals that they merit further study, which would doubtless glean additional forms.

It has been deemed advisable to report on the desmid flora in a series of papers, each treating a group of related genera or, in some cases, a single genus if the number of represented species warrants it. In this paper Cosmarium species have been brought together. This genus is usually well represented in any desmid flora, as it is in that of the Isle Royale region, but the percentage of Cosmarium species in these collections is not so great as in those which I have examined from the Southern Peninsula of Michigan and elsewhere.

It is noteworthy that the number of large Cosmarium species appearing in these collections is greater than usual. The writer has examined many collections from north temperate habitats, but in none has noted such an array of large and beautiful forms of Cosmarium. Of these large species *C. ovale*, *C. Eloiseanum*, *C. tetraophthalmum*, and *C. tuddalense* are the most numerous. The last species is particularly common in Hidden Lake, where the acidity is pH 6.0.

In subsequent and concluding papers it is expected that a summarizing check list for all desmid species will be given, together with habitat distribution on the island. This listing will permit the in-

[1] These samples were collected in the biological survey of Isle Royale conducted by the University of Michigan and authorized by the Fifty-fifth Legislature of the State of Michigan.

clusion of additional species of Cosmarium and representatives of other genera which may appear in the final analyses of the samples.

An interesting number of species in the following list are new records for North America, while some are reported for the first time from Michigan. Although many desmid species have shown significant and well-known limitations in their distribution, others seem to reveal no specificity for environmental factors. The appearance of *C. bimamillatum* in north temperate waters, for instance, is very unexpected. This plant has previously been found in the tropics and south of the equator. It is rare in one collection from Isle Royale. *C. tuddalense*, on the other hand, is an example of a species which, so far as present knowledge indicates, tends to maintain a definite distribution in north temperate habitats. It is known to occur only in a belt across northern Europe, Newfoundland, and northern United States (probably through Canada also).

List of Species

Cosmarium alpestre Roy & Biss.; West and West, *British Desmidiaceae*, III : 24, Pl. LXVII, Fig. 14. 1908.

Length 78–82 μ, width 58–60 μ. Smaller than usually described for this species. Pl. II, Fig. 9. Moose Lake.

Cosmarium angulare Johnson, *Bull. Torr. Bot. Club*, 21, Pl. 211, Fig. 14. 1894.

Length 31.2 μ, width 27.3 μ, isthmus 7.8 μ. Rare in one collection. Pl. I, Fig. 4. Wallace Lake.

Cosmarium bimamillatum Krieger, *Archiv f. Hydrobiol.*, Suppl. XI : 171, Pl. XIII, Fig. 3. 1932.

Length 35 μ, width 31.2 μ, isthmus 11 μ. Pl. IV, Fig. 18. Moose Lake.

The appearance of this subtropical plant in a north temperate habitat is of interest. It was first described from Sunda Islands; forma *minor* Rich has been reported from South Africa.

Cosmarium Boeckii Wille; West and West, *British Desmidiaceae*, III : 234, Pl. LXXXVI, Figs. 26–32. 1908.

Length 35 μ, width 35 μ, isthmus 8–10 μ. Pl. III, Fig. 7. Siskowit Lake.

Cosmarium Botrytis Menegh.; West and West, *British Desmidiaceae*, IV : 1, Pl. XCVI, Figs. 1–2, 5–15. 1911.

Length 57 μ, width 48–60 μ, isthmus 17–22 μ. Among mosses in rain pool at top of Scoville Point.

A form of this species which appears very commonly in some of the samples is much like one figured by Boldt, *Bihang kongl. vet.-akad. handl.*, 13, Pl. 2, Fig. 31. 1888. A specimen is illustrated on Pl. III, Fig. 4.

Cosmarium Botrytis Menegh. var. mediolaeve W. West; West and West, *British Desmidiaceae*, IV : 6, Pl. XCVII, Fig. 5. 1911.

Length 54.5 μ, width 46.8 μ, isthmus 15.6 μ. Pl. II, Figs. 2–3. Among mosses in rain pool at top of Scoville Point.

Cosmarium Botrytis Menegh. var. tumidum Wolle; West and West, *British Desmidiaceae*, IV : 5, Pl. XCVII, Figs. 2–3. 1911.

Length 68 μ, width 55 μ, isthmus 17 μ. Pl. III, Fig. 12. On dripping cliffs, Passage Island.

Cosmarium columbianum G. S. West, *Mém. de la Soc. neuchâteloise des sci. nat.*, V : 1036, Pl. 23, Figs. 68–69. 1914.

Length 39 μ, width 31.2 μ, thickness 19.5 μ, isthmus 9.7 μ. Pl. III, Fig. 11. Hidden Lake.

This plant should be compared with *C. Moerlianum* Lütkem., *Verh. d. k. k. zool.-bot. Ges.*, 42 : 554, Pl. 8, Fig. 7. 1892. Apparently this is the first time that *C. columbianum* has been reported since its discovery in 1914, and its appearance in northern Michigan is of interest from the standpoint of distribution.

Cosmarium connatum De Bréb.; West and West, *British Desmidiaceae*, III : 25, Pl. LXVII, Figs. 15–17. 1908.

Length 82 μ, width 60 μ, isthmus 28 μ. Pl. II, Fig. 13. Moose Lake.

Cosmarium contractum Kirchn. var. ellipsoideum (Elfv.) W. & G. S. West, *British Desmidiaceae*, II : 172, Pl. LXVI, Figs. 28, 35. 1905.

Length 20–22 μ, width 21–22 μ, isthmus 6–7 μ. This is a small form of the species but otherwise is identical. Pl. I, Fig. 6. Among mosses in rain pool at top of Scoville Point.

Cosmarium costatum Nordst.; West and West, *British Desmidiaceae*, III : 239, Pl. LXXXVII, Figs. 13–16. 1908.

Length 32–35 μ, width 26–27.3 μ, isthmus 11.7–14 μ. Pl. II, Fig. 4. Among Utricularia plants in Hidden Lake. New record for Michigan.

This plant was originally described from arctic and alpine re-

gions. Its appearance in the Isle Royale flora is in line with its occurrence in northern England, upon the unusualness of which the Wests remark (*op. cit.*, p. 240).

Cosmarium crenatum Ralfs; West and West, *British Desmidiaceae*, IV : 35, Pl. XCVIII, Figs. 9–12. 1911.

Length 27 μ, width 19 μ, isthmus 7.5–8 μ. Pl. IV, Fig. 6. Among filamentous algae in moose tracks at edge of swamp.

Cosmarium Debaryi Arch.; West and West, *British Desmidiaceae*, III : 61, Pl. LXX, Figs. 14–16; Pl. XCIII, Fig. 2. 1908.

Length 105.3 μ, width 46.8 μ, isthmus 31.2 μ. Pl. IV, Fig. 3. Moose Lake.

This large species, with its distinctive chloroplast, has not been found in Michigan before and has been reported but a few times from North America. Although having a record from Brazil, the plant seems to be confined to north temperate habitats of northern Europe, New England, and British Columbia.

Cosmarium difficile Lütkem. var. dilatatum Borge, *Arkiv f. Bot.*, 19 : 4, Pl. 1, Fig. 38. 1925.

Length 23 μ, width 17.5 μ, isthmus 5 μ. Pl. IV, Fig. 11. Moose Lake. New record for Michigan.

Cosmarium Eloiseanum Wolle; West and West, *Trans. Linn. Soc. London* (Botany), 5 : 248, Pl. XV, Fig. 22. 1896.

Length 98 μ, width 71 μ, isthmus 19.5 μ. Pl. II, Fig. 5. Moose Lake. New record for Michigan.

Cosmarium elongatum Racib.; Borge, *Arkiv f. Bot.*, 18 : 8, Pl. 1, Fig. 4. 1923.

Length 94–97 μ, width 39–41 μ, isthmus 35 36 μ. Pl. II, Fig. 8. Moose Lake. New record for Michigan.

Cosmarium furcatospermum W. & G. S. West, *British Desmidiaceae*, III : 206, Pl. LXXXIV, Figs. 8 10; Pl. LXXXI, Figs. 10–11. 1908.

Length 19 μ, width 15–17 μ, isthmus 6 μ. Pl. I, Figs. 16, 26. Hidden Lake. New record for Michigan.

Cosmarium granatum De Bréb. var. subgranatum Nordst. Forma of Borge, *Arkiv f. Bot.*, 1 : 95, Pl. 3, Fig. 12. 1903.

Length 32 μ, width 22 23 μ, isthmus 7.5 8.3 μ. Pl. IV, Fig. 8. Wallace Lake. New record for Michigan.

Cosmarium holmiense Lund.; West and West, *British Desmidiaceae*, III : 1, Pl. LXV, Figs. 1–2. 1908.

Length 42 μ, width 25–27 μ, isthmus 14–16 μ. Pl. I, Fig. 10. Among mosses in rain pool at top of Scoville Point. New record for Michigan.

Cosmarium holmiense Lund. var. integrum Lund.; West and West, *British Desmidiaceae*, III : 2, Pl. LXV, Figs. 3, 5. 1908.

Length 53.8 μ, width 35.2 μ, isthmus 19.5 μ. Pl. I, Fig. 7. Rare, in rain pool at top of Scoville Point. New record for Michigan.

Cosmarium impressulum Elfv.; West and West, *British Desmidiaceae*, III : 86, Pl. LXXII, Figs. 14–18. 1908.

Length 25–28 μ, width 19–22 μ, isthmus 6 μ. Pl. I, Fig. 24. Hidden Lake. New record for Michigan.

Cosmarium impressulum Elfv. f. suborthogonum (Racib.) W. & G. S. West; Taylor, *Pap. Mich. Acad. Sci., Arts, and Letters*, 19 : 255, Pl. XLVIII, Fig. 20. 1934.

Length 19.5 μ, width 15–17 μ, isthmus 9 μ. Pl. I, Fig. 11. Among mosses in rain pool at top of Scoville Point. New record for Michigan.

Cosmarium margaritatum (Lund.) Roy & Biss.; West and West, *British Desmidiaceae*, IV : 18, Pl. XCIX, Figs. 8, 10. 1911.

Length 75–79.5 μ, width 60–63 μ, isthmus 21–22 μ. Pl. IV, Fig. 4. Hidden Lake.

Cosmarium Meneghinii De Bréb.; West and West, *British Desmidiaceae*, III : 90, Pl. LXXII, Figs. 29–32. 1908.

Length 10–13 μ, width 9.5–16 μ, isthmus 4.5 μ. Pl. I, Fig. 12. Among mosses in rain pool at top of Scoville Point.

Cosmarium modestum W. & G. S. West, *Journ. Linn. Soc. Bot.*, 33 : 304, Pl. 17, Fig. 12. 1898.

Length 21.4 μ, width 19.5 μ, isthmus 5.8 μ. Pl. I, Figs. 27–28. Lake Ritchie.

Our specimens seem to be consistently smaller than those originally described, but otherwise apparently agree with the type.

Cosmarium Novae-Semliae Wille var. sibericum Boldt; West and West, *British Desmidiaceae*, III : 36, Pl. LXVIII, Figs. 17–18. 1908.

Length 17 μ, width 15 μ, isthmus 7 μ. Pl. IV, Fig. 9. Hidden Lake. New record for Michigan.

Cosmarium ochthodes Nordst.; West and West, *British Desmidiaceae*, IV : 10, Pl. XCVIII, Figs. 1–3. 1911. Forma.

Length 78 μ, width 58.5 μ, isthmus 15.6 μ. Pl. III, Fig. 14. Siskowit Lake.

Cosmarium ochthodes Nordst. var. amoebum W. West; West and West, *British Desmidiaceae*, IV : 11, Pl. XCVIII, Figs. 4–6. 1911.

Length 82.5 μ, width 63.4 μ, isthmus 24.3 μ. Pl. IV, Fig. 17. Moose Lake. New record for Michigan.

Cosmarium ornatum Ralfs; West and West, *British Desmidiaceae*, III : 151, Pl. LXXVIII, Figs. 1–10. 1908.

Length 39 μ, width 35.2 μ, isthmus 11.7 μ. Pl. IV, Fig. 7. Wallace Lake. New record for Michigan.

Cosmarium ovale Ralfs; West and West, *British Desmidiaceae*, III : 267, Pl. XCII, Fig. 1; Pl. XCIII, Fig. 1; Pl. XCIV, Fig. 1. 1908.

Length 150–163 μ, width 94–95 μ, isthmus 36–38 μ. With a single row of granules across the base of the semicell. This basal row of granules is a characteristic not noted in the original description of *C. ovale*, nor figured in the published illustrations of the species. The writer observed a somewhat similar expression in plants collected in the mountain lakes of western Idaho. Pl. II, Fig. 1. Hidden Lake.

Cosmarium pachydermum Lund.; West and West, *British Desmidiaceae*, II : 139, Pl. LVII, Fig. 7. 1905.

Length 105–109 μ, width 83–85.8 μ, isthmus 37–39 μ. Pl. IV, Fig. 13. Hidden Lake.

Cosmarium perforatum Lund.; West and West, *British Desmidiaceae*, II : 143, Pl. LVIII, Figs. 4–5. 1905.

Length 62.4 μ, width 60.4 μ, isthmus 31.2 μ. Pl. II, Fig. 6. Hidden Lake. New record for Michigan.

Cosmarium plicatum Reinsch var. hibernicum W. West; West and West, *British Desmidiaceae*, III : 61, Pl. LXX, Figs. 12 13. 1908.

Length 62.4 μ, width 35.2 μ, isthmus 19.5 μ. Pl. I, Fig. 19. This shows an abnormal cell, in which daughter semicells have failed to separate. Gull Island, Rock Harbor.

Cosmarium Portianum Arch.; West and West, *British Desmidiaceae*, III : 165, Pl. LXXX, Figs. 4–7. 1908.

Length 33–58 μ, width 26–44 μ, isthmus 10–15 μ. Pl. III, Fig. 6. Among mosses in rain pool at top of Scoville Point.

Cosmarium praegrande Lund.; West and West, *British Desmidiaceae*, III : 150, Pl. LXXVII, Fig. 19. 1908.

Length 91–93 μ, width 53–55 μ, isthmus 20 μ. Pl. II, Fig. 7. Moose Lake. New record for Michigan.

Cosmarium protractum (Naeg.) De Bary; West and West, *British*

Desmidiaceae, III : 181, Pl. LXXXII, Fig. 8; Pl. XCIV, Figs. 4–5. 1908.

Length 33 μ, width 31.5 μ, isthmus 9 μ. Pl. I, Fig. 15; Pl. III, Fig. 2. Bat Island, Rock Harbor.

Cosmarium Pseudobroomei Wolle; West and West, *British Desmidiaceae*, IV : 22, Pl. C, Figs. 7–8; Pl. CIII, Fig. 7. 1911.

Length 39 μ, width 42 μ, isthmus 10 μ. Pl. IV, Fig. 14. Hidden Lake.

Cosmarium pseudonitidulum Nordst.; West and West, *British Desmidiaceae*, II : 195, Pl. LXIII, Fig. 26. 1905.

Length 46.8 μ, width 35.1 μ, isthmus 15.6 μ. Pl. I, Fig. 5. Wallace Lake. New record for Michigan.

Cosmarium pseudoprotuberans Kirchn.; West and West, *British Desmidiaceae*, III : 82, Pl. LXXII, Figs. 6–8. 1908.

Length 25 μ, width 24 μ, isthmus 9 μ. Pl. IV, Fig. 10. Wallace Lake.

Cosmarium pseudopyramidatum Lund.; West and West, *British Desmidiaceae*, II : 201, Pl. LXIV, Figs. 9–12. 1905.

Length 48.7 μ, width 31 μ, isthmus 9–11.5 μ. Pl. I, Fig. 13. Moose Lake.

Cosmarium pyramidatum De Bréb.; West and West, *British Desmidiaceae*, II : 199, Pl. LXIV, Figs. 5–7. 1905.

Length 81.9 μ, width 50.7 μ, isthmus 15.6 μ. Pl. II, Fig. 10. Hidden Lake.

A form of this species is shown on Pl. II, Fig. 12. It has the proportions of a form figured by Taylor, *Pap. Mich. Acad. Sci., Arts, and Letters*, 19, Pl. XLVIII, Fig. 17. 1934. A character of the specimen which is worthy of note is the presence of a central slightly swollen and shining area in the face of the semicell. A similar feature was observed by Taylor (*op. cit.*, p. 261, Pl. L, Fig. 7) in his *C. pseudopyramidatum* var. *lentiferum*, with which the Isle Royale form of *C. pyramidatum* should be compared.

Cosmarium quadratum Ralfs; West and West, *British Desmidiaceae*, III : 57, Pl. LXX, Figs. 5–8. 1908.

Length 74 μ, width 39 μ, isthmus 27.3 μ. Pl. I, Fig. 1. Hidden Lake.

Cosmarium Raciborskii Lag.; Homfeld, *Pflanzen.*, 12 : 53, Pl. VII, Fig. 74. 1929.

Length 54.6 μ, width 55 μ, thickness 31 μ, isthmus 25 μ.

Pl. III, Fig. 9; Pl. IV, Fig. 1. Hidden Lake. New record for Michigan.

Cosmarium rectangulare Grun.; West and West, *British Desmidiaceae*, III : 54, Pl. LXX, Figs. 1–2. 1908.

Length 39 μ, width 35.2 μ, isthmus 9.7 μ. Pl. I, Figs. 22, 25. Hidden Lake. New record for Michigan.

Cosmarium rectangulare Grun. var. hexagonum (Elfv.) W. & G. S. West, *British Desmidiaceae*, III : 56, Pl. LXX, Fig. 4. 1908.

Length 43.9 μ, width 32.2 μ, isthmus 9.7 μ. Pl. I, Fig. 18. Moose Lake.

Cosmarium scopulorum Borge, *Arkiv f. Bot.*, 18 : 12, Pl. 1, Fig. 14. 1922.

Length 23.4 μ, width 19.5 μ, isthmus 3.9 μ. Pl. I, Fig. 9. Bat Island, Rock Harbor. New record for Michigan. Previously reported only from North Dakota.

Cosmarium sexangulare Lund.; West and West, *British Desmidiaceae*, III : 81, Pl. LXXII, Fig. 3. 1908.

Length 43 μ, width 36 μ, isthmus 11 μ. Hidden Lake.

Cosmarium sexangulare Lund. f. minima Nordst.; West and West, *British Desmidiaceae*, III : 82, Pl. LXXII, Figs. 4–5. 1908.

Length 27.3 μ, width 23 μ, isthmus 7.5 μ. Not quite so small as this form is usually described; otherwise identical. Pl. I, Fig. 14. Hidden Lake.

Cosmarium speciosum Lund. var. Rostafinskii (Gutw.) W. & G. S. West f. americana W. & G. S. West (*C. Rostafinskii* var. *americana* W. & G. S. West, *Journ. Linn. Soc. Bot.*, 33 : 279, Pl. 17, Fig. 13. 1897).

Length 40.5 μ, width 26.6 μ, isthmus 17.2 μ. Our specimens slightly larger than measurements usually given for this species. Pl. III, Fig. 3. Hidden Lake. Tobin Harbor. New record for Michigan.

Cosmarium speciosum Lund. var. simplex Nordst. f. intermedia Wille, *Öf. k. vet.-akad. förh.*, p. 41, Pl. 12, Fig. 29. 1879; West and West, *British Desmidiaceae*, III : 251, Pl. LXXXIX, Fig. 7. 1908.

Length 38.5–40 μ, width 27.3–29 μ, isthmus 19.5 21 μ. Pl. I, Figs. 23, 29. Gull Island, Rock Harbor.

This plant is questionably assigned here. In our specimens the

sinus tends to be more open than in *C. speciosum simplex* as figured by the Wests and others. Also there are fewer crenulations in ours, particularly in front view. Two rows of crenulations are visible in side view, one on either side of a median line of the semicell.

Cosmarium sportella De Bréb. var. subnudum W. & G. S. West, *British Desmidiaceae*, III : 186, Pl. LXXXII, Fig. 14. 1908.

Length 50–53 μ, width 39–41 μ, isthmus 23–24 μ. Pl. III, Fig. 8; Pl. IV, Fig. 15. Wallace Lake. New record for North America.

Cosmarium subcrenatum Hantz.; West and West, *British Desmidiaceae*, III : 228, Pl. LXXXVI, Figs. 10–14. 1908.

Length 31.2 μ, width 31.2 μ, isthmus 9.7 μ. Pl. II, Fig. 11. Moose Lake.

Forms of this species are shown on Pl. III, Fig. 5; Pl. IV, Fig. 12. Besides these there commonly appears a form which has very slightly undulate margins, becoming smooth in the center of the semicell. This is very similar to a form of Taylor's, *Pap. Mich. Acad. Sci., Arts, and Letters*, 19 : 266, Pl. XLVIII, Fig. 16. 1934.

Cosmarium subspeciosum Nordst.; West and West, *British Desmidiaceae*, III : 252, Pl. LXXXIX, Fig. 11. 1908.

Length 58.5 μ, width 43.9 μ, isthmus 13.6 μ. Pl. III, Fig. 1. Moose Lake.

Cosmarium subtumidum Nordst.; West and West, *British Desmidiaceae*, II : 192, Pl. LXIII, Figs. 18–20. 1905.

Length 35.2 μ, width 27 μ, isthmus 11.7 μ. Pl. I, Figs. 2–3. Moose Lake.

Cosmarium subundulatum Wille; West and West, *British Desmidiaceae*, II : 151, Pl. LIX, Figs. 13–15. 1905.

Length 39 μ, width 27 μ, isthmus 15.6 μ. Pl. IV, Figs. 2, 16. Moose Lake. New record for Michigan.

Our specimens are slightly smaller than measurements usually given for this species; otherwise identical, particularly in respect to the scrobiculations as described by the Wests (*l. c.*).

Cosmarium taxichondrum Lund.; West and West, *British Desmidiaceae*, IV : 45, Pl. CIII, Figs. 11–13. 1911. Forma.

Length 40–43 μ, width 33–38 μ, isthmus 10–11 μ. Pl. IV, Fig. 19. Moose Lake. Tobin Harbor.

This form is very similar to var. *nudum* Turner (*Kongl. sv. vet.-akad. handl.*, 25, Pl. 8, Fig. 64. 1892), and perhaps should be assigned to the position of a form of this variety. However, *C. taxichondrum* exhibits a great variety of modifications in its granulations and it is difficult, and perhaps confusing, to attempt to give each expression a name.

Cosmarium tetragonum (Naeg.) Arch. var. Lundellii Cooke; West and West, *British Desmidiaceae*, III : 18, Pl. LXVI, Figs. 23 - 24. 1908.

Length 36 μ, width 22 μ, isthmus 9 μ. Pl. I, Fig. 8. Hidden Lake.

Our specimens show in the wall very fine ridges, which are so arranged as to form a geometric figure. These cannot be seen except in the empty cells.

Cosmarium tetraophthalmum De Bréb.; West and West, *British Desmidiaceae*, III : 270, Pl. XCV, Figs. 4–7. 1908.

Length 105–110 μ, width 74–81 μ, isthmus 28–31 μ. Pl. III, Fig. 10. Moose Lake. New record for Michigan.

Cosmarium trilobulatum Reinsch; West and West, *British Desmidiaceae*, II : 185, Pl. LXII, Figs. 28–30. 1905.

Length 25.4 μ, width 21.4 μ, isthmus 4.5 μ. Pl. IV, Fig. 5. Moose Lake. Tobin Harbor. New record for Michigan.

Cosmarium tuddalense Ström, *Nyt. Mag. f. Natur.*, 57 : 29, Pl. 4, Fig. 8. 1919.

Length 101.5 μ, width 72–75 μ, isthmus 23–25 μ. Pl. I, Fig. 17. Hidden Lake. New record for Michigan.

Cosmarium venustum (De Bréb.) Arch.; West and West, *British Desmidiaceae*, III : 8, Pl. LXVI, Figs. 1–3. 1908.

Length 41.9 μ, width 27.3 μ, isthmus 5.8 μ. Pl. I, Fig. 20. Moose Lake.

Cosmarium venustum (De Bréb.) Arch. var. excavatum (Eichl. et Gutw.) W. West f. duplo-major Gutw.; Grönblad, *Acta soc. pro fauna et flora fenn.*, 49 : 37, Pl. 7, Figs. 18–19. 1921.

Length 40 μ, width 27 μ, isthmus 4.5 μ. Pl. I, Fig. 21. Moose Lake. New record for North America.

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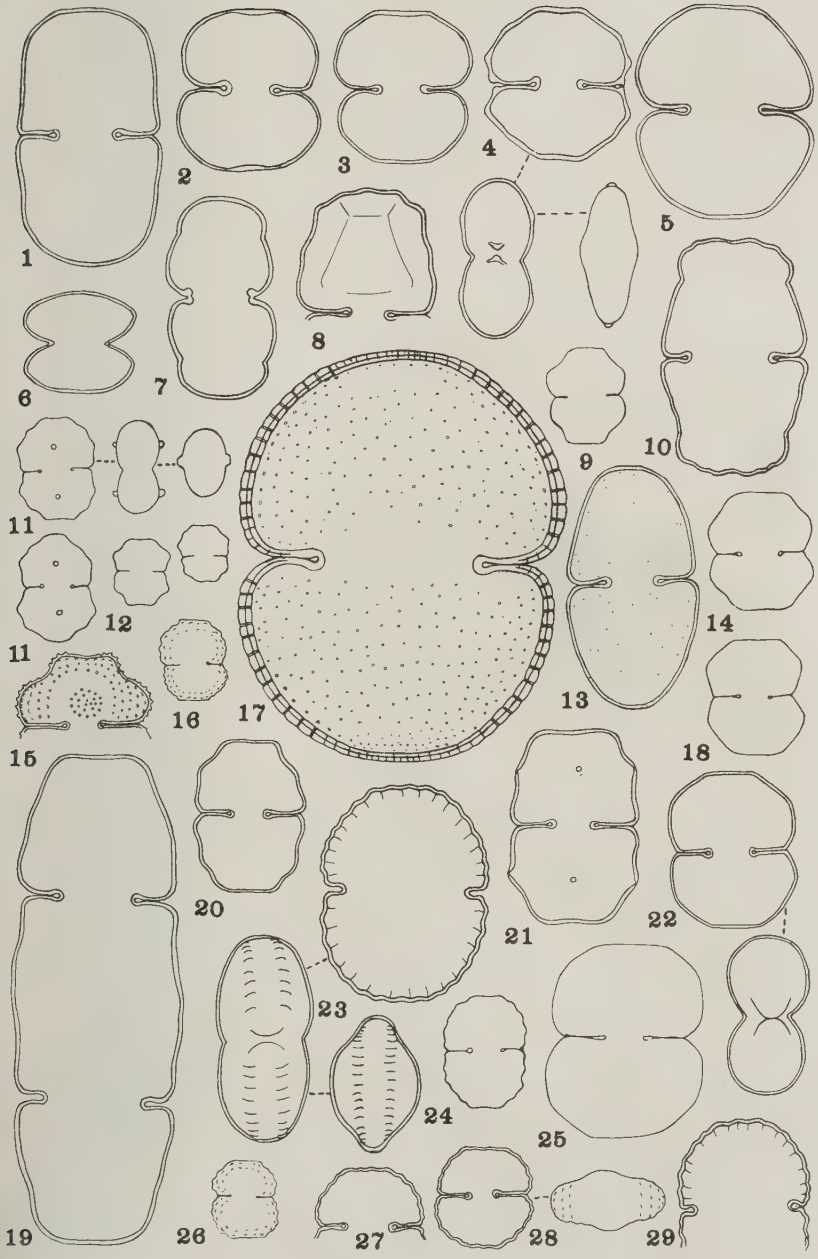
EXPLANATION OF PLATE I

Cosmarium

1. C. quadratum Ralfs, × 500
2–3. C. subtumidum Nordst., × 750
4. C. angulare Johnson, × 750
5. C. pseudonitidulum Nordst., × 750
6. C. contractum Kirchn. var. ellipsoideum (Elfv.) W. & G. S. West, × 750
7. C. holmiense Lund. var. integrum Lund., × 500
8. C. tetragonum (Naeg.) Arch. var. Lundellii Cooke, × 880
9. C. scopulorum Borge, × 500
10. C. holmiense Lund., × 750
11. C. impressulum Elfv. f. suborthogonum (Racib.) W. & G. S. West, × 750
12. C. Meneghinii De Bréb., × 750
13. C. pseudopyramidatum Lund., × 600
14. C. sexangulare Lund. f. minima Nordst., × 600
15. C. protractum (Naeg.) De Bary, × 600
16. C. furcatospermum W. & G. S. West, × 600
17. C. tuddalense Ström, × 600
18. C. rectangulare Grun. var. hexagonum (Elfv.) W. & G. S. West, × 440
19. C. plicatum Reinsch var. hibernicum W. West, × 650
20. C. venustum (De Bréb.) Arch., × 550
21. C. venustum (De Bréb.) Arch. var. excavatum (Eichl. et Gutw.) W. West f. duplo-major Gutw., × 650
22. C. rectangulare Grun., × 500
23. C. speciosum Lund. var. simplex Nordst. f. intermedia Wille, × 850
24. C. impressulum Elfv., × 550
25. C. rectangulare Grun., × 600
26. C. furcatospermum W. & G. S. West, × 600
27–28. C. modestum W. & G. S. West, × 750
29. C. speciosum Lund. var. simplex Nordst. f. intermedia Wille, × 650

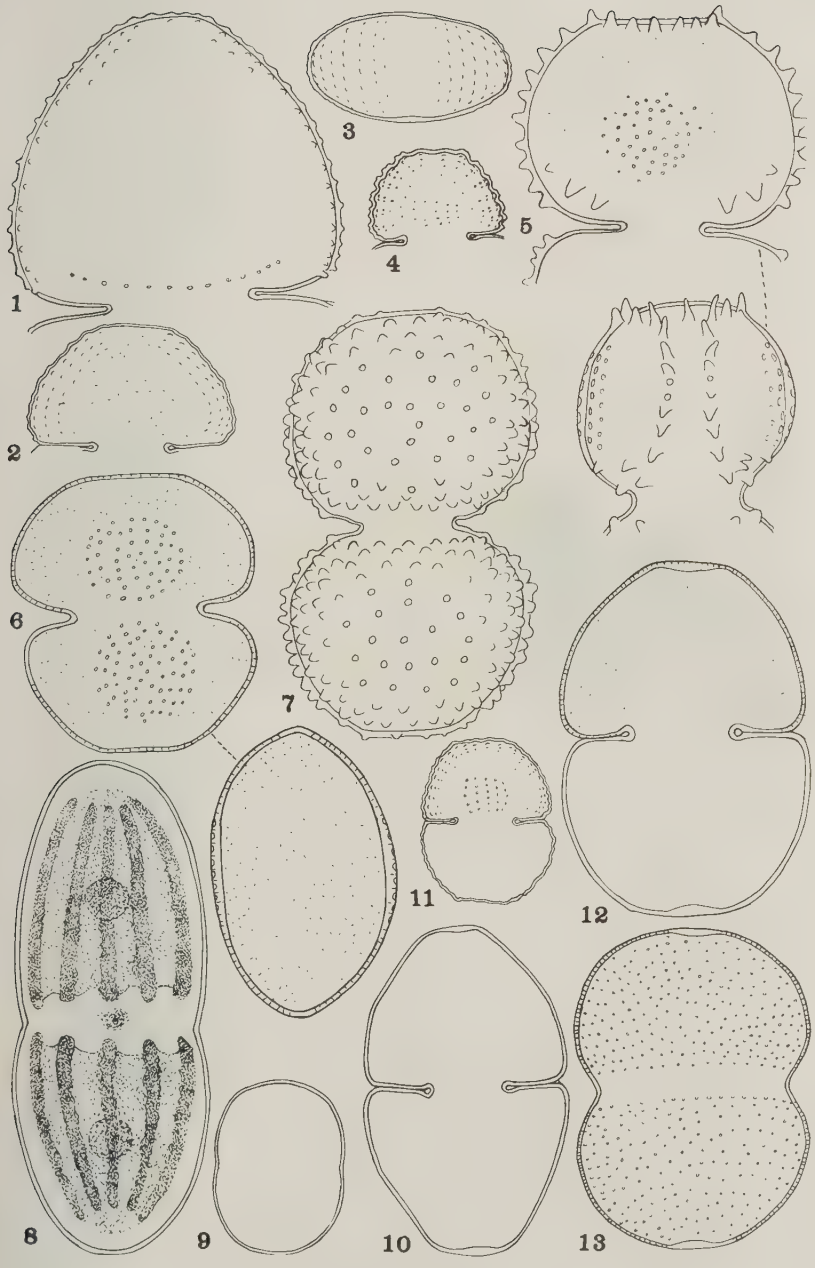


Desmids of Isle Royale

EXPLANATION OF PLATE II

Cosmarium

1. C. ovale Ralfs, × 500
2 3. C. Botrytis Menegh. var. mediolaeve W. West, × 600
4. C. costatum Nordst., × 750
5. C. Eloiseanum Wolle, × 600
6. C. perforatum Lund., × 600
7. C. praegrande Lund., × 700
8. C. elongatum Racib., × 700
9. C. alpestre Roy & Biss., × 440
10. C. pyramidatum De Bréb., × 600
11. C. subcrenatum Hantz., × 600
12. C. pyramidatum De Bréb., forma, × 700
13. C. connatum De Bréb., × 500

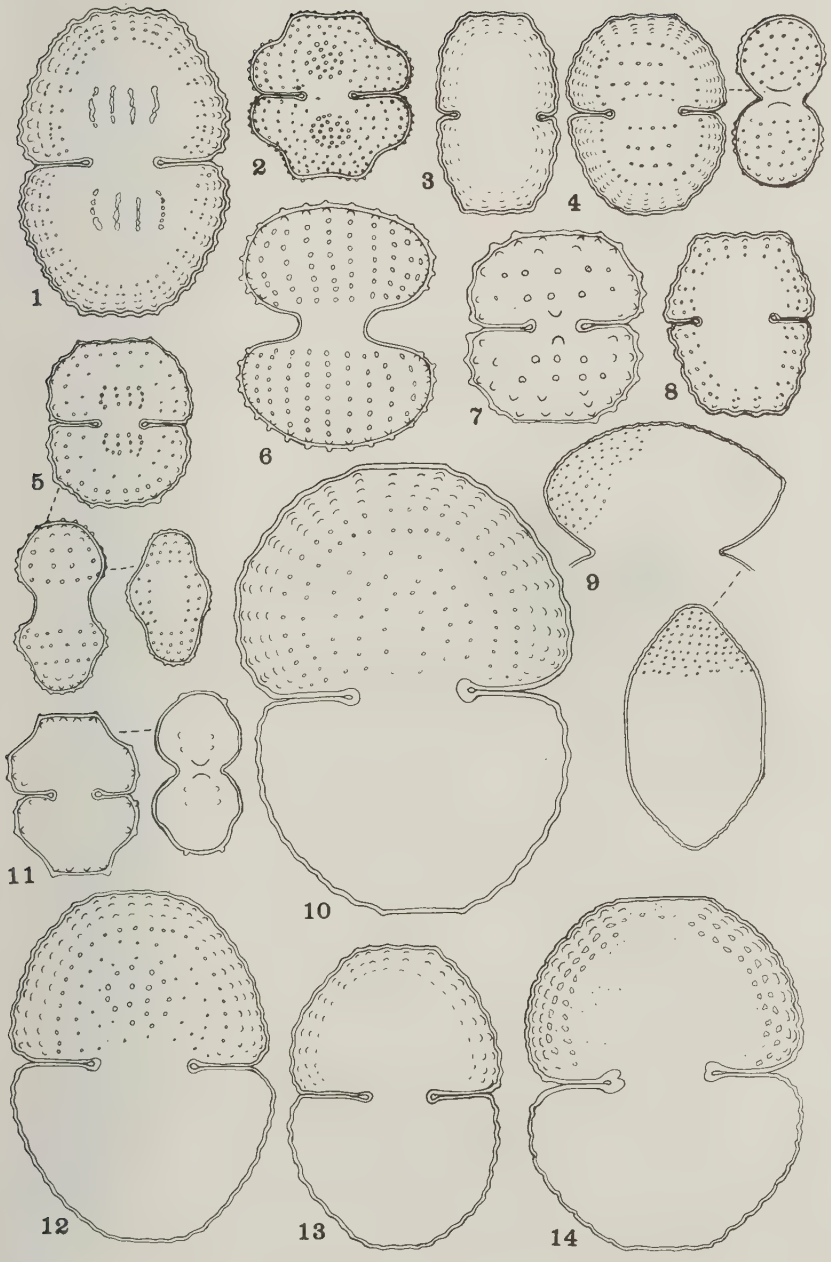


Desmids of Isle Royale

EXPLANATION OF PLATE III

Cosmarium

1. C. subspeciosum Nordst., × 650
2. C. protractum (Naeg.) De Bary, × 700
3. C. speciosum Lund. var. Rostafinskii (Gutw.) W. & G. S. West f. americana W. & G. S. West, × 650
4. C. Botrytis Menegh., forma, × 440
5. C. subcrenatum Hantz., forma, × 650
6. C. Portianum Arch., × 750
7. C. Boeckii Wille, × 700
8. C. sportella De Bréb. var. subnudum W. & G. S. West, × 500
9. C. Raciborskii Lag., × 650
10. C. tetraophthalmum De Bréb., × 650
11. C. columbianum G. S. West, × 600
12. C. Botrytis Menegh. var. tumidum Wolle, × 650
13. C. Botrytis Menegh. var. mediolaeve W. West, forma, × 600
14. C. ochthodes Nordst., × 650

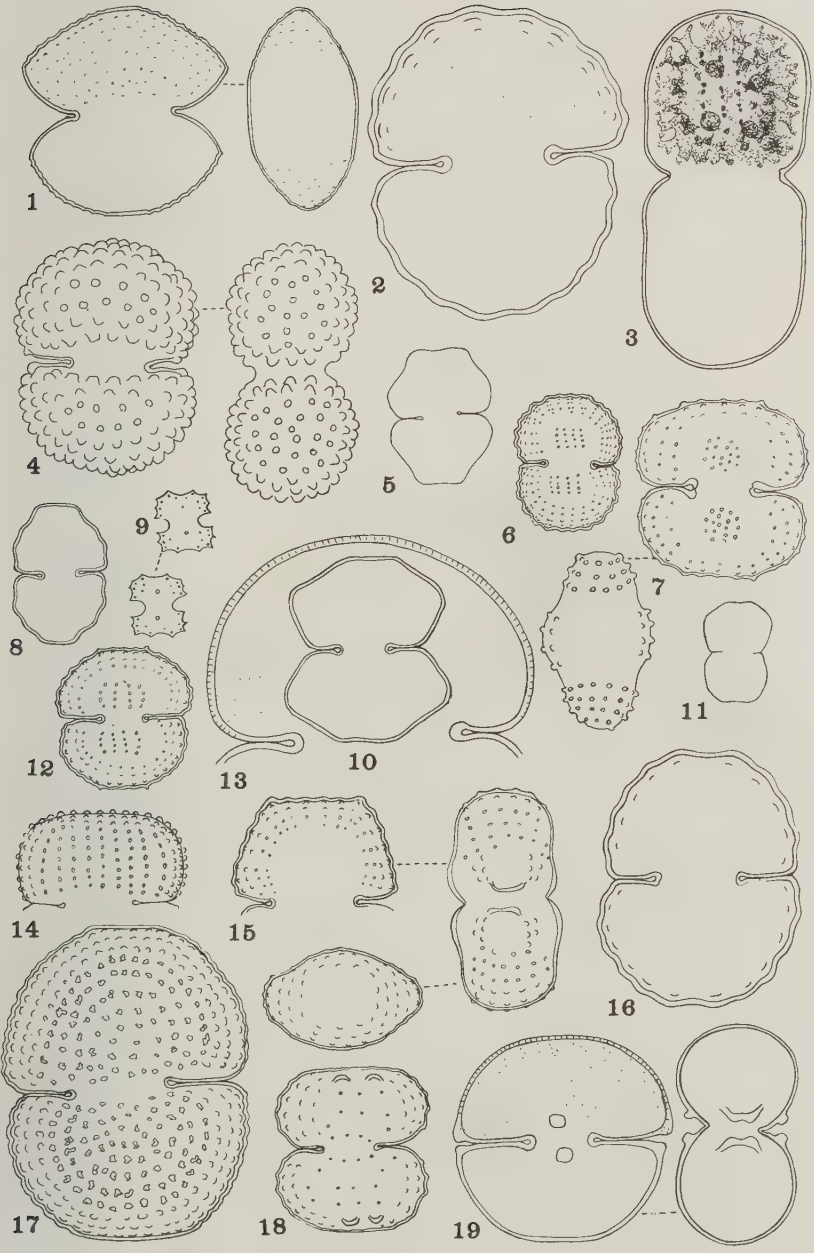


Desmids of Isle Royale

EXPLANATION OF PLATE IV

Cosmarium

1. C. Raciborskii Lag., × 500
2. C. subundulatum Wille, forma, × 1000
3. C. Debaryi Arch., × 500
4. C. margaritatum (Lund.) Roy & Biss., × 440
5. C. trilobulatum Reinsch, × 1000
6. C. crenatum Ralfs, × 750
7. C. ornatum Ralfs, × 650
8. C. granatum De Bréb. var. subgranatum Nordst., forma, × 500
9. C. Novae-Semliae Wille var. sibericum Boldt, × 500
10. C. pseudoprotuberans Kirchn., × 900
11. C. difficile Lütkem. var. dilatatum Borge, × 800
12. C. subcrenatum Hantz., forma, × 600
13. C. pachydermum Lund., × 500
14. C. Pseudobroomei Wolle, × 650
15. C. sportella De Bréb. var. subnudum W. & G. S. West, × 500
16. C. subundulatum Wille, × 1000
17. C. ochthodes Nordst. var. amoebum W. West, × 500
18. C. bimamillatum Krieger, × 650
19. C. taxichondrum Lund., forma, × 850



Desmids of Isle Royale

UNUSUAL AGARICS FROM MICHIGAN. V*

ALEXANDER H. SMITH

THE season of 1936 was very hot and dry during the summer months, but a rather wet September followed. During the latter part of September and early in October the mushroom flora in the vicinity of Ann Arbor was unusually rich and varied. Certain collections were of exceptional interest. *Marasmius chordalis* Fr., a rather common species under Douglas fir in the Olympic Peninsula of Washington, was found under oak in the George Reserve, near Pinckney. The conifer plantations at Saginaw Forest, near Ann Arbor, presented an unusual situation owing to the presence of many species not previously reported for the state. This is astonishing because the area has been studied intensively since 1929. Of these species *Cortinarius balteatus* Fr., *Cortinarius nigrellus* Peck, *Lepiota Cortinarius* Lange, and *Gomphidius ochraceus* Kauffman were particularly interesting. In all, sixteen species are here discussed, fifteen of which are apparently new records for Michigan.

A solution of five parts chloral hydrate, two parts water, and an excess of iodine was used to determine the iodine reaction of the spores. The collection numbers and the photographs are the writer's unless otherwise stated. All the collections are deposited in the Herbarium of the University of Michigan. All color names in quotation marks are taken from R. Ridgway, *Color Standards and Color Nomenclature*, 1912.

List of Species

Cortinarius balteatus Fr. (Pl. I). — Pileus 8–15 (20) cm. broad, convex to plane or at times the margin irregular and the disk depressed, viscid but soon dry, at first "livid violet" to "lobelia violet," changing to vinaceous violet or "purple-drab," at times "Perilla purple" on the disk, in age becoming "liver brown" to "carob brown" if wet, near "tawny-olive" when dry, a per-

* Papers from the Herbarium of the University of Michigan.

sistent "lobelia violet" tinge present in a marginal zone, surface more or less uneven, the disk often subareolate, margin silky or appressed-fibrillose and long remaining inrolled; flesh very thick and firm, whitish, odor and taste mild; lamellae close to crowded, narrow at first, moderately broad in age, white or whitish at first, at times pale violaceous near the margin (almost to the stipe in some) before becoming dull cinnamon brown, adnexed to sinuate with a decurrent tooth; stipe 4–8 cm. × 2–3 cm., at first broadly bulbous, tapering to a point below, in age equal above a tapering base, solid and firm, white within, fibrillose near the base from the "Saccardo's violet" veil, white and silky above; spores 9–12 × 5–6.5 μ, amygdaliform, roughened.

Gregarious in a rather dry spruce plantation, Saginaw Forest, Ann Arbor, Sept. 28, 1936 (4933), and under oak and hickory as well as in a plantation of oak and pine, Saginaw Forest, Oct. 7, 1936 (5060). Lange (10) mentions lilac scales at the base of the stem. In these collections the fibrillose remnants at the base of the stem were quite evenly distributed. The spores of my collections agree with the measurements of Bresadola (1) and are slightly larger than those of Herpell, Lange, and Rea. Kauffman (6) reports this species from New York and Colorado, but the form he described possessed a whitish cortinate margin and a yellow ocher pileus at first. Kauffman considered this a form of the species. Apparently the Michigan collections represent the first report of typical material from North America. Small fruiting bodies in my collections compare very well with the illustrations of Fries (2) and Bresadola (1). The gill color was quite variable and puzzling. In unexpanded buttons the gills were white or grayish and remained so until the veils were broken and the caps were partly expanded. In these immature pilei and in later stages the gills became "mauve" near the margin and in a few they became dull violaceous up to the point of attachment to the stipe. This color was soon clouded over by the maturing spores. Forms with violaceous gills might be mistaken for *Cortinarius largus* Fr., but the white flesh and the lilac zone around the margin of the cap readily distinguish them.

Psathyrella subatrata (Fr.) Gillet (Pl. II). — Pileus (15) 20–40 mm. broad, oval at first, obtusely conic at maturity, glabrous, moist, "russet," "cinnamon-brown," "Prout's brown" or "ochra-

ceous-tawny," hygrophanous, fading to "warm buff," "light ochraceous-buff," or paler, in age sometimes "warm buff" on the disk and "wood brown" to "avellaneous" near the margin, margin striate when moist, surface smooth or slightly rugulose and atomate when caps have faded, no indications of a veil; flesh watery and extremely fragile, thin, odor and taste mild; lamellae close, narrow, adnate but soon seceding, "cinnamon-buff" to "pinkish cinnamon," soon dark blackish brown with white fimbriate edges; stipe 10–15 cm. × 3–5 mm., equal, strict, fragile, splitting readily, hollow, glabrous or faintly silky, dull white, no indications of a veil at any stage; spores 12–16 × 7–8 μ (4992) or 14–17 × 7–8.5 μ (5003), smooth, dull blackish brown under the microscope, ellipsoid; cystidia 35–50 × 9–15 μ, fusoid-ventricose, on the gill edge only; basidia four-spored; pileus trama corticated by a more or less compact palisade of clavate to pyriform cells, occasional brown-walled setae present, 100–250 × 4–6 μ, projecting, thick-walled.

Gregarious or in small clusters of two or three fruit bodies on very rotten débris in an open oak woods, Silver Lake, Dexter, Oct. 2, 1936 (4992); on soil and débris in an oak woods, Ann Arbor, Oct. 2 (5003); and on soil in a low woods of elm and ash, Lakeland, Oct. 4 (5021). Some of the larger fruiting bodies in No. 4992 were sterile and much brighter than the fertile caps. This species is not well known in North America (Morgan, 12). In Michigan it has been confused with *Psathyra umbonata* Peck, a species resembling it somewhat in stature, spore size, and cystidia, but which apparently lacks the characteristic thick-walled setae on the pileus. Fries' (2) figure of *P. subatrata* illustrates the Michigan collections well, and Dr. Robert Kühner, of Paris, to whom I sent material for confirmation, stated in a letter that the specimens checked in every respect with *P. subatrata*.

Tricholoma brevipes (Fr. ex Bull.) Quél. *sensu* Lange. — Pileus (1–3) 4–7 cm. broad, broadly umbonate to convex, becoming plane, margin long remaining inrolled but finally plane and somewhat wavy, surface moist and unpolished, dark fuliginous at first, becoming buffy brown or paler, hygrophanous, ashy when faded; flesh thick, white, odor and taste not distinctive; lamellae narrow to moderately broad, crowded, adnate, becoming emarginate, white, creamy in age, edge even; stipe 1–4 cm. × 6–10

mm., base clavate at first, in age often tapering evenly downward, white or buff, often becoming sordid in age, more or less fibrillose below, pruinose above; spores 7–8 × 4–5 μ; ellipsoid, dark violet gray in iodine, very minutely roughened; cystidia rare to scattered on the gill edge, 26–38 × 6–9 μ, smooth or with a slight incrustation at the apex, aciculate above a slightly inflated base; pileus trama homogeneous.

Gregarious on a new seeding of grass, Univ. of Mich. campus, June 26 (45) and July 3, 1934 (51). These collections are the same as material from New York determined by Kauffman. Lange (11) also considers this to be the true *T. brevipes*. Bresadola (1) illustrated and described a very different fungus under the same name. Lange places the latter next to *Tricholoma grammopodium*. A fungus similar to Bresadola's was collected in the vicinity of Muskegon, Oct. 11, 1936 (5031). The pilei were "clay color" and up to 12 cm. broad. The gills were whitish. The stipe was whitish above but streaked by dark gray fibrils below, and at the base the color was sordid grayish brown. The spores measure 8–9 × 4–5 μ, become dark violet gray in iodine, and are slightly roughened at maturity. Whether or not this form should be regarded as a species distinct from *T. grammopodium* (Fr. ex Bull.) Quél. *sensu* Lange cannot be determined until more material is available for comparison. The fungus identified as *T. grammopodium* in Kauffman and Smith (7) is *Tricholoma arcuatum* f. *robustum* Lange (11). Typical specimens of *T. grammopodium sensu* Lange were collected at the George Reserve, Pinckney, Aug. 9 (1759) and Aug. 10, 1935 (1780).

Tricholoma orirubens Quél. — Pileus 3 10 cm. broad, convex, becoming plane or obtusely umbonate, surface dry, appressed-fibrillose or minutely lacerate-scaly, usually streaked with darker fibrils, "benzo brown" to dark violaceous gray on the disk, whitish to cinereous toward the margin, sometimes tinged orange on the margin or over all in age, margin opaque and cottony to subtomentose; flesh thick, white, firm, becoming "light salmon-orange" when cut or bruised, odor and taste farinaceous; lamellae close, broad, adnexed, white, soon flushed with "light salmon-orange," edge slightly irregular; stipe 4 7 cm. × 10–18 mm., solid, equal above a subradicating base, faintly silky at first, white, in age flushed over all with "light salmon-orange," no indi-

cations of a veil; spores 5–5.5 × 4–4.5 μ, broadly ovoid, pale yellow in iodine; basidia four-spored; cystidia not differentiated; pileus trama homogeneous, cuticle of interwoven threads.

Singly under oak, Dexter, Oct. 2 (4996), Ann Arbor, Oct. 14 (6058), and the George Reserve at Pinckney, Oct. 15, 1936 (6070). The color of the pileus is quite variable, but the violaceous gray tinge on the disk was constant. The color change of the flesh was very characteristic and at times caused the caps to be tinged salmon-orange. Lange (11), who describes and illustrates the species very well, says the color change is often slight. This species has apparently not been reported previously from North America. It is closely related to *Tricholoma terreum*, from which it differs in the more violaceous gray colors and the changing flesh.

Tricholoma terriferum Peck (Pl. III). — Pileus 5–8 cm. broad, convex, becoming broadly convex, viscid when wet, glabrous or disk appearing slightly virgate because of agglutinated appressed fibrils, margin sometimes ribbed in age, color "army brown" on the disk to "fawn color" near the margin, in age often "wood brown" over all; flesh thick, firm, white, taste farinaceous, odor mild or faintly farinaceous; lamellae close, crowded, rather sharply adnexed, broad (8–10 mm.), white, when bruised or in age becoming slightly sordid but not reddish brown, edge even; stipe 4–6 cm. × 10–14 mm., equal or the base slightly inflated, rounded below, solid, white or tinged pallid incarnate brown, staining faintly yellowish brown when handled, apex pruinose, glabrous or silky below; spores 5–6 × 3.5–4 μ, ellipsoid, yellowish in iodine; basidia four-spored; cystidia not differentiated; pileus trama homogeneous beneath a gelatinous pellicle.

Cespitose to gregarious in an arc under elm and basswood, Stockbridge, Oct. 4, 1936 (5031). The pilei were covered by dirt and débris, as described by Peck (16). This is a common occurrence among fleshy fungi which have viscid pilei. The spores of the type measure 4–4.5 × 3–3.5 μ and remain nearly hyaline or become faintly yellowish in iodine. Murrill (13) states that the species is known only from the type locality. A collection by Dearness, Oct., 1930, from Ontario, is deposited in the New York State Museum Herbarium along with the type. This species is closely related to such European species as *Tricholoma albobrun-*

neum and *Tricholoma ustale*, but differs in the gills not staining reddish brown. The change in color on the stipe is very slight.

Cortinarius nigrellus Peck (Pl. IV). — Gregarious to subcespitose in great abundance under spruce in a plantation at Saginaw Forest, Ann Arbor, Sept. 18 (3912), and again Sept. 28, 1936 (4942). The pilei measured 3–5 cm. broad. The colors were "seal brown" when fresh but faded to "walnut brown" or paler. When fading the pilei have "seal-brown" streaks on a "walnut-brown" ground color. The gills were "avellaneous" to "fawn color" at first and changed slowly to "army brown." The stipe was characterized by a distinct annular zone near the base. This zone and the fibrillose covering below it are tinged "vinaceous-brown." The apex of the stipe is silky and tinged violaceous to vinaceous brown.

Entoloma prunuloides (Fr.) Quél. (Pl. V). — Singly to subgregarious on grassy ground in an open oak woods, Ann Arbor, Oct. 3 (5010) and Oct. 13 (6053), and South Lyons, Oct. 6, 1936 (5045). Murrill (14) excluded this species in his study of the genus in North America. Although Kauffman (4) included it in his key, he had not collected the species in Michigan. The outstanding characters are the globoid spores, pale colors which tend to become yellowish in age, and the lubricous to subviscid pileus. The stems in the Michigan collections were unusually long for the species, and in this respect they resemble *Entoloma albidum* Murrill. The lamellae of the latter, however, are described as being rather narrow.

Gomphidius ochraceus Kauffman (Pl. VI). — Gregarious under pine, Saginaw Forest, Ann Arbor, Oct. 7 (5053) and Oct. 8, 1936 (5076, 5084). The cuticle of the pileus sometimes cracks in age, thus causing the appearance of spotlike scales. However, it is a truly glabrous species. The entire fruiting body becomes tinged with "peach red" in age.

Hygrophorus hypothejus Fr. — E. B. Mains (34–186), Little Lake, Sept. 13, 1934. This species was included by Kauffman (4) in his study of the Michigan flora, but he had not collected it in the state.

Inocybe fulvella Bres. — In troops at the edge of a pine plantation, Dexter, Oct. 18, 1936 (6118). Heim (3) uses the name *Inocybe scabella* var. *fulvella* (Bres.) Heim for this species. *I.*

scabella is thus used in the sense of Cooke for a tuberculate-spored species. In the United States the name is applied to a smooth-spored species; see Kauffman (5), who apparently followed the conception of Bresadola. Heim (3) has given the name *Inocybe Friesii* to this smooth-spored species.

Lactarius cinereus Peck. — Scattered under beech, Ann Arbor, Oct. 1 (4980), and Muskegon, under beech on the sand dune, Oct. 11, 1936 (6027). The fungus described as *L. cinereus* in Kauffman (4) is, as Kauffman suspected, the species described by Burlingham as *Lactarius mucidus*. The writer's collections cited above are identical with Burlingham's No. 574 of the Lactariae of North America, Fasc. III, and represent the first report of typical material from Michigan.

Lactarius mutabilis Peck. — Gregarious under oak and also under a species of Vaccinium at the edge of a bog, Ann Arbor, Sept. 29, 1936 (6172). The pilei measured 4–8.5 cm. broad and were "army brown" with "natal brown" watery zones when fresh. When faded they were "vinaceous-buff" with "fawn color" zones or azonate and evenly "vinaceous-buff" or "fawn color." The gills were "tilleul buff" at maturity.

Lepiota cortinarius Lange (Pl. VII). — Gregarious under spruce in a plantation at Saginaw Forest, Ann Arbor, Sept. 28 (4942), Oct. 7 (5058), and Oct. 16, 1936 (6098). Lange (8) mentions gilvous stains on the gills in age. My specimens were characteristic in this and in all other respects except that the gills were not crowded at maturity. The pilei measured 3–10 cm. broad. The spores measure 6–7.5 × 3 μ and become dark brown in iodine.

Marasmius chordalis Fr. — Singly on humus in an oak woods, George Reserve, Pinckney, Oct. 4, 1936 (5020). For a detailed account of this species see Smith (17). There has apparently been some confusion between *Marasmius elongatipes* Pk. and *M. chordalis*. The spores and colors readily separate them, but the former, because of a compact palisade layer of pyriform cells over the surface of the pileus, should be arranged in the same section with *M. chordalis*; see Patouillard (15).

Tricholoma cognatum (Fr.) Gill. *sensu* Lange. — Scattered on humus under beech and maple near Cross Village, June, 1935. The tan to ochraceous brown colors in all its parts are distinctive.

Tricholoma stridulum var. pallidipes Lange. — Scattered on

humus in oak woods around Ann Arbor. First collected by C. H. Kauffman, Oct. 20, 1926, and later by the writer July 26 and Aug. 8, 1935 (1661, 1714). Lange does not mention the taste of the flesh in his description. In my specimens and according to Kauffman's notes there was a very pronounced subnauseous flavor. When moist the pileus is "olive-brown" to "buffy brown" and in age fades to "pale smoke gray." The stipe is usually 6 10 cm. long and 4–6 mm. thick, but shorter-stemmed forms (3–6 cm. × 3–8 mm.) have been collected (1661).

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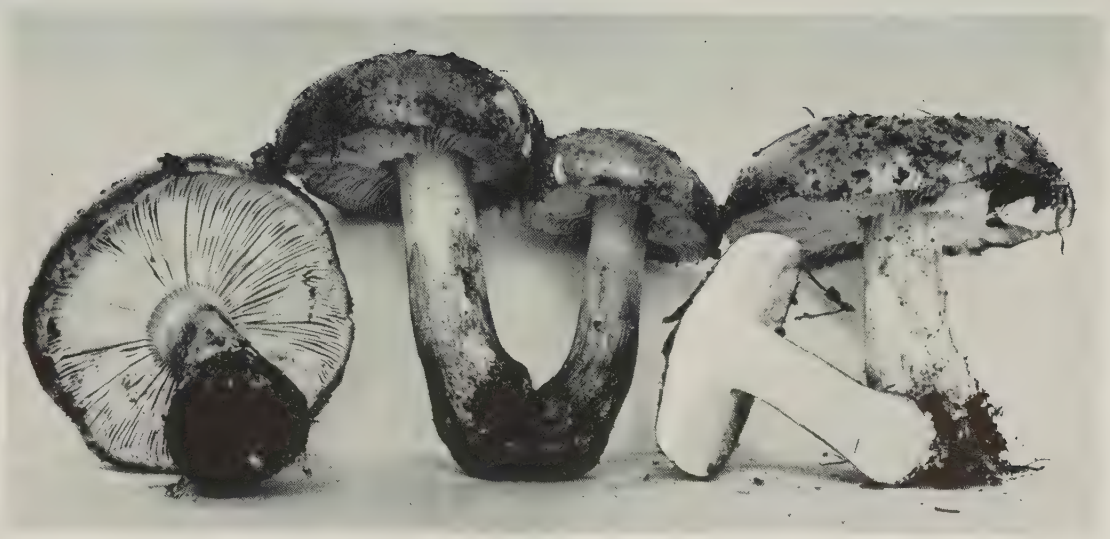
Cortinarius balteatus Fr., × ½

Psathyrella subatrata (Fr.) Gillet, × 1



Tricholoma terriferum Pk., × 1

Cortinarius nigrellus Pk., × 1

Entoloma prunuloides (Fr.) Quél., × 1

Gomphidius ochraceus Kauff., × 1

Lepiota Cortinarius Lange, × 1

NOTES ON FOSSIL PLANTS FROM HOG CREEK IN SOUTHWESTERN IDAHO *

HELEN V. SMITH

THE material described in this paper represents a small collection of leaf and seed impressions obtained from a bed of volcanic ash at Hog Creek near Weiser in southwestern Idaho. Most of the collection was made in the summer of 1934 by a party composed of Mr. O. J. Smith, Mr. H. M. Tucker, Mr. Wendell Smith, and the writer. Additional specimens were obtained from the College of Idaho.

The first fossil plants from this locality were gathered by Kirkham during his study of the geology of the region. His collections were made from five localities in the vicinity of Weiser and included twenty-one plant forms (7), eleven of which Berry determined specifically. More recently Dorf studied a larger collection from four localities in the same region which yielded a flora of forty-five species, six of which had been previously reported by Berry. In all, sixty-six plant forms have been reported from the Weiser beds and forty-two of these have been given specific names. In this paper ten species, two of which are new, are added to the flora of this area.

Since the geology of the region has been reviewed by Kirkham (7) and the present physical conditions and vegetation have recently been fully discussed by Dorf (5) no mention of them is necessary in this report.

The Hog Creek locality from which Dorf reported thirty-five species is included in the Idaho formation. Kirkham has shown this to be distinct from the Upper Miocene Payette formation which occurs in the same region. The age of the plant-bearing beds is considered to be Upper Miocene or Lower Pliocene. The fossil plants show a marked correlation with those of various Upper Miocene beds, notably the Latah and the Payette, whereas the vertebrate fauna and stratigraphy indicate a Pliocene age.

* Papers from the Department of Botany of the University of Michigan, No. 628.

There are thirty-two species in this collection, twenty-two of which are listed in this paper. The Coniferae are represented by six genera, among them *Sciadopitys* and *Glyptostrobus*, which are no longer found in America. One monocotyledonous plant is represented by fragments of leaves that might be referred to the form genus *Cyperacites*. The remaining species are distributed in eleven genera of the Dicotyledones. *Engelhardtia* is now only Asiatic, and the remaining genera are still present in the flora of the northwest, but, because of climatic changes, very few of them are now found in the vicinity of Hog Creek.

The distribution of the supposed modern equivalents of the fossil species in this collection shows the same relationships as those found by Dorf, namely, the majority occur in western United States, the remainder being divided chiefly between eastern America and eastern Asia.

The writer wishes to express her appreciation to Professor H. H. Bartlett for his interest and helpful suggestions during the course of the present investigation.

List of Species

Pinus sp. — Needles about 3.5 cm. long occur in fragmentary condition in fascicles of two. This is probably the same form that Dorf described as *Pinus sp.*

Picea lahontensis MacG. (Fig. 9). — Seed including wing 14 mm. long; body of seed slightly over 4.5 mm. long (measured obliquely) and 2 mm. wide, oblong, narrowed into a short falcate extension at the acute angle of the oblong base; apex obtuse or rounded; outer margin slightly concave from the widest point near the apex to the point of attachment to the seed body; greatest width of the wing 4.5 mm., narrowing to 3 mm. at the place of attachment; texture apparently membranaceous, but firm, without visible venation. The two specimens in this collection differ from the Trout Creek material as figured and described by MacGinitie (10) chiefly in their larger size. They differ from the specimen from Hog Creek figured by Dorf in their larger size and in lacking the visible venation. It is possible that these larger specimens represent a different species, but this can be determined only after studying a more extensive collection.

Sciadopitys americana, n. sp. (Fig. 1). — Needle linear, thick; 6.3 cm. long (or longer), 2 mm. broad; sides almost parallel, tapering very slightly to the blunt base, and less to the apex, which appears to be bluntly rounded; surface marked by longitudinal grooves or furrows.

This single needle bears a striking resemblance to those of the umbrella pine, *Sciadopitys verticillata* Sieb. & Zucc., needles of which are shown for comparison (Figs. 2–3). *Sciadopitys,* a monotopyic genus native to Japan, is characterized by two types of leaves; by the scale leaves, which are borne along the stems and crowded in whorls at the ends of the shoots; and by the linear leaves, which are borne in whorls of 20 to 30 in the axils of the scale leaves. The linear leaves are in reality two united leaves borne on undeveloped spurs, as in *Pinus.*

Although the central furrow marking the fusion of the two needles is not very distinct, it can be made out in some portions of the fossil as distinctly as on the upper surface of the leaf of the living species. The length of the leaf prevents the plant from being placed in *Keteleeria, Torreya, Cephalotaxus,* or *Cunninghamia.* These genera also differ in having leaves with more pointed apices. The apparent thickness of the specimen and the nature of the markings are such as to exclude it from the Monocotyledones.

There has been no fossil record of *Sciadopitys* in the Tertiary of the United States.

Sequoia Langsdorfii (Brnt.) Heer. — As is to be expected in the later Tertiary formations, *Sequoia* is but sparsely represented. A single specimen may be referred to this species.

Glyptostrobus europaeus Lesq. (Fig. 14). — *Glyptostrobus* is one of the formerly widespread genera now confined to eastern Asia. Like *Taxodium,* to which it is closely related, it is characterized by having two types of branchlets. The perennial branchlets bear a single type of leaf and the annual branchlets bear either of two types. The leaves on the annual branchlets may be either flat and linear on the seedlings or falcate-acicular on the mature trees. The leaves on the perennial branchlets are small and scalelike and resemble leaves of *Cupressus,* from which they can be distinguished by their alternate instead of opposite arrangement. The leaves figured are characteristic of the perennial branchlets.

Brooks (1) has recently suggested a change in name for the American species of *Glyptostrobus* on the ground that "the identification of the American specimens with the European species is not positive." Henry and M'Intyre (6), who have considered this question in connection with their study of the living *Glyptostrobus*, hold that the Tertiary specimens constitute a single species indistinguishable from the modern one. Until such time as a distinction other than geographic can be demonstrated, it seems preferable to include all the specimens under the older name.

Thuja Garmani Lesq. (Fig. 11). — The single frond of *Thuja* shows the characteristically flattened 2-ranked sprays with leaves closely appressed, the leaves on some of the branchlets being greatly elongated and somewhat keeled. It is closely related to *Thuja plicata* Don, a specimen of which from northern Idaho is shown in Figure 10.

Engelhardtia Tuckeri, n. sp. (Fig. 4). — *Engelhardtia*, a genus of five or six species confined to India, Malaya, China, and Formosa, is represented in this collection by a single beautifully preserved bract and its counterpart.

Bract three-lobed, the middle lobe being the larger, 4.2 cm. long and 1.1 cm. broad; lateral lobes 3.7 cm. long and 1.1 cm. in width; sinuses acute, forming an angle of about 45 degrees; medial wing with approximately parallel sides rounded to a broad apex; lateral wings with subparallel sides, asymmetrically tapering to a rounded apex; primary venation of three strong veins which extend to the apices of the lobes, that of the middle lobe straight and tapering distally, those of the lateral lobes curved and tapering; secondaries either alternate or subopposite, about four pairs in each lobe, slender, very distinct, curving upward to arch and forming loops with adjacent secondaries or strong tertiaries just within the margin; tertiary venation distinct, forming a polygonal or a quadrangular reticulum; seed not present.

A bract from a species of *Engelhardtia* from the vicinity of Tourane, Annam, Indo-China, in the Herbarium of the University of Michigan is figured (Fig. 5) for a comparison of the general aspect and venation. The fossil species closely resembles *Engelhardtia rigida* Bl. and *Engelhardtia spicata* var. *aceriflora* Kds. & Val. of Java.

Leaves referred to *Engelhardtia* have been reported from a number of American localities, but none is recognized in this collection. Fossil species based on bracts unlike the specimens in this collection have also been reported from a number of localities, among them *Engelhardtia oxyptera* Saporta, from the Miocene at Florissant, Colorado, and two species from the Wilcox beds.

This species is named in honor of Mr. Harold M. Tucker, botanist at the College of Idaho, who has rendered valuable assistance in the collection of specimens from the Hog Creek beds.

SALIX SP. — Small specimens unlike *Salix coalingensis* Dorf reported from the Hog Creek locality are quite similar to a small specimen of *Salix californica* Lesq. figured by Chaney (3) and may belong to the latter species.

ALNUS CORRALLINA Lesq. — This species, which has recently been critically studied by Brown (2), is represented by a single specimen that is unmistakably similar to the living species, *Alnus rhombifolia* Nutt. This alder was widely distributed in the Miocene of western America and a similar form, *Alnus Merriami*, has been described by Dorf (4) from the Pliocene of California.

CASTANOPSIS CONVEXA (Lesq.) Brooks. — *Quercus convexa* Lesq. has recently been removed to *Castanopsis* by Brooks (1) because of the ultimate nervation. This species is represented by a number of well-preserved specimens which show the entire margins, venation characters, size, and shape that relate the fossils to *Castanopsis sempervirens* (Kellogg) Dudley, a Californian species.

QUERCUS CLARNENSIS Trelease. — This characteristic well-represented oak has been recorded, under various names, only from the Lower Miocene of the Crooked River Basin, and has been refigured and redescribed by Chaney (3), with whose figures and descriptions the specimens in this collection appear to be identical.

QUERCUS SIMULATA Knowl. — This disposition of my specimens is made because of Dorf's reference of similar material to this species, and because of LaMotte's statement (9) that *Quercus consimilis* Newb., which my specimens resemble greatly, is a Lower Miocene form and *Q. simulata* is Upper Miocene.

QUERCUS TRAINI MacG. — It is with some hesitation that a specimen is referred to this species, since Dorf has reported the closely related *Quercus Browni* Brooks from the Weiser beds. However, if there is a specific distinction between these plants, which are

both similar to the variable *Q. chrysolepis* Lieb., the specimen in this collection is better referred to *Q. Traini.*

Platanus dissecta Lesq. — This well-known species is represented by fragments of leaves and by a petiole showing the characteristic enlarged base.

Amelanchier dignatus (Knowl.) Brown. — Since a number of Tertiary species referred to *Amelanchier* appear to be indistinguishable from the living *Amelanchier alnifolia* Nutt., the writer is accepting the name and the synonymy given by Brown (2). *Amelanchier* had a wide distribution during the Tertiary. Miocene forms have been reported from the John Day and Crooked River basins of Oregon, the Grand Coulee in Washington, the Salmon River beds in eastern Idaho, and from as far east as the Florissant beds of Colorado. Pliocene forms comparable with the modern *A. alnifolia* have been reported from California. *A. alnifolia* now occurs over the western part of the continent from Alaska to northern California and eastward to northern Michigan.

Acer Chaneyi Knowl. — This maple is characterized by slender, deeply cut lobes, which give it a rather fragile appearance. In this collection it is found in association with seeds of *Acer negundoides* MacG. and *Acer oregonianum* Knowl. No samaras referable to this leaf species have been recognized in this collection.

Acer negundoides MacG. (Fig. 13). Several samaras with the greatly elongated seeds characteristic of this species are included in the collection.

Acer oregonianum Knowl. — Three samaras similar to those described by Knowlton (8) are included in the collection. The distinction between this species and the samaras described by Chaney (3) as *Acer Osmonti* is not clear. MacGinitie (10) and others (5, 8) consider these to be seeds of *Acer Merriami* Knowl. No leaves of *A. Merriami* are included in this collection.

Arbutus Matthesii Chaney. — This species is represented by several well-preserved specimens which appear to have been "skeletonized" and which show the venation in detail. They differ from figured specimens from other localities in their smaller size and relatively narrower leaves. Although the generally accepted living equivalent of *A. Matthesii* is *Arbutus Menziesii* Pursh among the living species studied in the Herbarium of the University of Michigan, the resemblance to *Arbutus canariensis* L. was

found to be greater. Because of the geographic isolation of the Canary Islands, *A. canariensis* can scarcely be considered to be a living representative of this fossil species.

Fraxinus Coulteri Dorf (Fig. 8). — This species is represented by a single specimen that differs in some particulars from the specimens previously described and figured. In this specimen the seed is obscure rather than prominent, the strong midvein in the wing is lacking, and the wing is broader and apparently has a blunt apex. Dorf compared his fruits with *Fraxinus oregona* Nutt., but they also show a similarity to *Fraxinus americana* L. (Fig. 12). The differences between the fossils in the two collections may be significant, but they are not considered sufficient to form a second species of *Fraxinus*, based on so small an amount of material.

Symphoricarpos salmonensis Brown. — This species is represented by a single specimen that agrees in all details with the figure given by Brown (2). The coralberry, *Symphoricarpos orbiculatus* Moench, which seems to be the living species closest to this fossil, is now widely distributed, occurring from New York to Georgia and westward to Montana and Colorado and south to Texas.

Symphoricarpos elegans (Lesq.), new comb. — (*Celastrinites elegans* Lesq., *U. S. Geol. Surv., Terr. Rep.*, Vol. 8 [Cret. and Tert. Fl.], p. 185, pl. 31, fig. 9. 1883; Knowlton, *Proc. U. S. Nat. Mus.*, 51: 281, pl. 21, fig. 7. 1917).

Leaves small, nearly orbicular, with base decurrent to the short petiole; margin entire or slightly wavy near the apex; midrib slightly sinuous, giving off approximately six pairs of subopposite alternate secondaries; secondaries also slightly sinuous, general course being parallel, given off at narrow angles of divergence, in some cases paralleling the midrib for a short distance before passing into the blade, lowermost secondaries running almost along the edge of the leaf and forking occasionally, effaced along the borders; 2.5 cm. long, 1.5 cm. broad; texture membranaceous.

The fossil leaves can be duplicated by specimens of *Symphoricarpos racemosus* Michx., figures of which are given for comparison (Figs. 7, 15). The fossil specimen (Fig. 6) is from Succor Creek near Rockville, Oregon. The Hog Creek specimens are not so well preserved, but nevertheless are typical.

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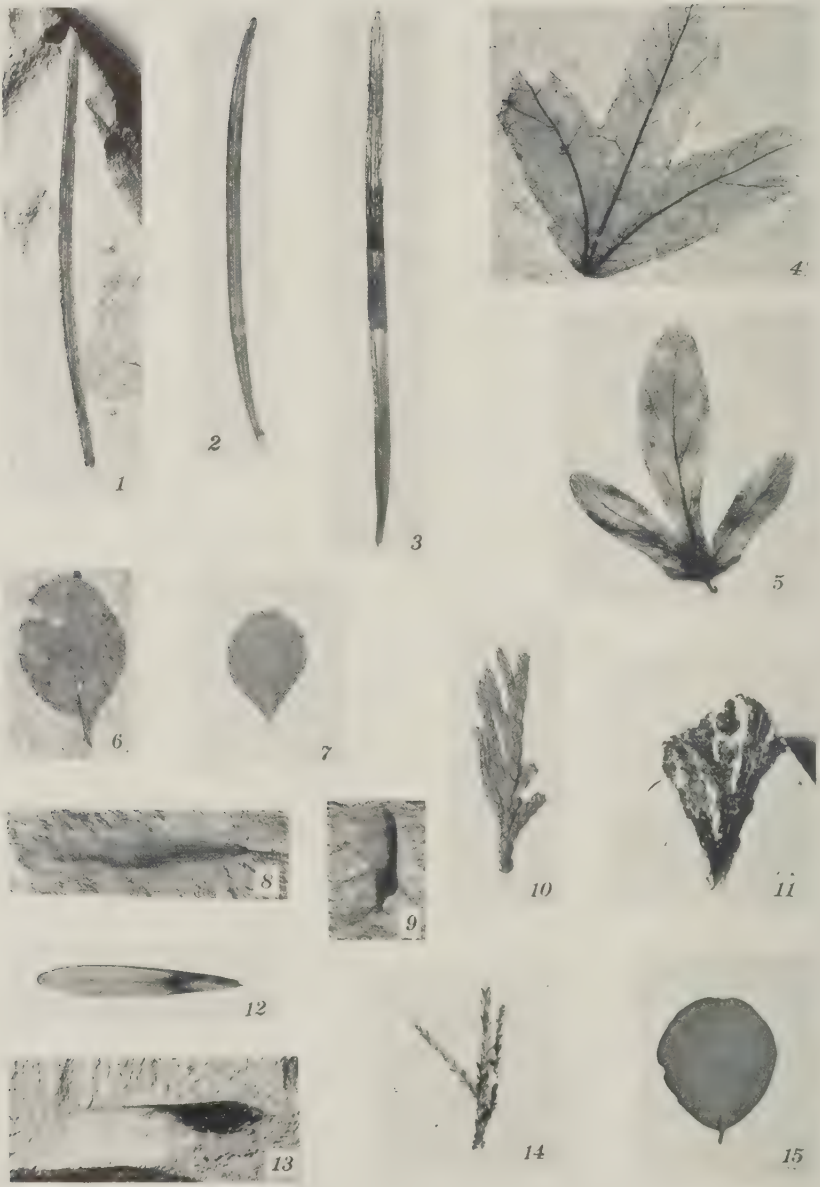

Fossil plants from Hog Creek in southwestern Idaho

EXPLANATION OF PLATE I

FIG. 1. *Sciadopitys americana* Helen Smith. Type; Mus. Pal., Univ. of Mich., No. 18694

FIGS. 2–3. *Sciadopitys verticillata* Sieb. & Zucc. Specimens from the Arnold Arboretum in the Herbarium, Univ. of Mich.

FIG. 4. *Engelhardtia Tuckeri* Helen Smith. Type; Mus. Pal., Univ. of Mich., No. 18695

FIG. 5. *Engelhardtia sp.* from Tourane, Annam, Indo-China, in the Herbarium, Univ. of Mich.

FIG. 6. *Symphoricarpos elegans* (Lesq.) Helen Smith

FIGS. 7, 15. *Symphoricarpos racemosus* Michx. Specimens from Colorado in the Herbarium, Univ. of Mich.

FIG. 8. *Fraxinus Coulteri* Dorf

FIG. 9. *Picea lahontensis* MacG.

FIG. 10. *Thuja plicata* Don. Specimen from Idaho in the Herbarium, Univ. of Mich.

FIG. 11. *Thuja Garmani* Lesq.

FIG. 12. *Fraxinus americana* L. Specimen from Porter County, Indiana, in the Herbarium, Univ. of Mich.

FIG. 13. *Acer negundoides* MacG.

FIG. 14. *Glyptostrobus europaeus* Lesq.

CULTURAL LIFE HISTORIES OF MELANCONIS AND PSEUDOVALSA. III *

THE GENUS PROSTHECIUM FRES. EMEND. PETRAK

LEWIS E. WEHMEYER

THE genus Melanconis, as described by the Tulasnes (7, p. 115), is a very loose and heterogeneous grouping whose only apparent common denominator is the presence of dark-colored conidia, of the Melanconium–Coryneum–Stilbospora type, which stain the surface of the substratum. Since the time of the Tulasnes a number of genera have been segregated from this complex, chiefly upon the basis of the spore color and septation, and many new species have been added to these various segregates. In recasting this general group it is necessary, therefore, to reanalyze the natural relationships within these genera. In doing so we see that the present distribution of species by no means follows the natural groupings. Within the genus Pseudovalsa, for instance, we find species which should naturally be placed in Massaria (*P. occulta* (Schw.) E. & E.), Aglaospora (*P. profusa*, etc.), Calospora (*P. platanoides*, etc.), Prosthecium (*P. macrosperma*, etc.), Thyridaria (*P. minima, P. comptoniae*, etc.), and other genera. The first problem is the definition and limitation of natural generic groupings. This paper is concerned chiefly with the genus Prosthecium.

The genus Prosthecium was erected by Fresenius (3, p. 62) for the members of the Sphaeriales with appendaged spores, and *P. ellipsosporum* Fres. (*Pseudovalsa macrosperma* (Tul.) Sacc.) was given as the type species. In 1923 Petrak (6, p. 324) emended Fresenius' genus to include those species of Pseudovalsa having appendaged spores and only slightly differentiated entostromata, without marginal zones, and gave *P. macrosperma, P. hapalocystis*, and *P. Berkeleyi* as species belonging here. The writer believes this to be a

* Papers from the Department of Botany of the University of Michigan, No. 626.

naturally related group, which also shows similarities in the conidial stage. The genus Pseudovalsa Ces. & de Not. as typified by *P. lanciformis* includes a distinct group of species, such as *P. umbonata*, *P. longipes*, and *P. sigmoidea*, which have a well-developed, dark-colored entostromata, nonappendaged spores, and a Coryneum conidial stage. The Prosthecium group, including *P. caudata*, *P. bicornis*, *P. aucta* (*Melanconis dolosa*?), and *P. stylospora*, in addition to those mentioned by Petrak, have no, or very little, entostromatic development, but possess appendaged spores and two types of conidia: one four-celled, hyaline or brown, borne within cavities in an ectostroma (Stilbospora); and one one-celled, hyaline, ellipsoid to fusoid or allantoid, and much smaller.

This group can again be broken up into two rather distinct sections, which may be designated as follows:

Euprosthecium: Ectostroma present, often strongly developed, light in color; entostroma slightly or poorly developed; ostioles erumpent through an ectostromatic disc; spores usually hyaline for a time, at least, before maturing, appendages short, caplike, evanescent. *P. macrosperma*, *P. platanoides*, *P. aucta*, *P. stylospora*.

Pseudoprosthecium: Ectostroma very minute or absent; entostroma none; ostioles convergent and fused into an erumpent disc; spores hyaline, or mostly brown, appendages elongate, curved or coiled, more persistent. *P. caudata*, *P. Berkeleyi*, *P. hapalocystis*, *P. bicornis*.

P. caudata and *P. Berkeleyi* are more or less intermediate between these two groups, having a slight ectostromatic development at first. There are also several species of Melanconis, as *M. thelebola*, *M. occulta*, and *M. dolosa*, which must likewise be considered in relation to this group. The species of the genus Massariovalsa must also be differentiated, if possible, from Pseudoprosthecium. More cultural data in regard to conidial connections and details of stromatal development are needed for such comparisons. The following connections are presented as an aid in this direction.

Melanconis thelebola (Fr.) Sacc.

Melanconis thelebola, described as *Sphaeria thelebola* by Fries, is a well-known and widely distributed species, on Alnus, which illus-

trates some most interesting relationships. The perithecial stromata (Pl. I, Fig. 1) have small, light-colored, white to yellow-brown ectostromata and sometimes a slight entostromatic development in the bark about the circinate perithecia. In this respect it is typical of the genus Melanconis. There is often, however, a blackening of the bark surface which may penetrate into the bark and continue as a partial marginal zone (Pl. I, Fig. 1), recalling the genus Diaporthe. The large asci (100–195 × 12–21 μ) and the large spores (30 45 × 8–11 μ) with long-filiform, curved appendages (Pl. II, Fig. 2) again suggest certain species of the Prosthecium group already mentioned. This latter relationship is supported by the fact that the spores are occasionally three- to four-celled (Wehm. Herb. No. 3656) and when old may become brownish (Allesch. & Schnab., Fung. Bav. No. 253).

The Tulasnes (7, p. 167) describe and figure this species under the name *Aglaospora thelebola* and also mention that the spores may become four-celled and brown. They describe the conidial stages as consisting of one-celled, hyaline, allantoid spermatia, 7 × 1 μ, and oblong to pyriform, two- to three-celled, dark-brown stylospores, 20–30 × 6.5–10 μ, both formed in depressed-globose cavities within an ectostroma.

Similar conidial stages have been found by the writer associated with *M. thelebola* in nature (Fung. Col. No. 3144; Wehm. Herb. Nos. 3042, 3843). The conidial cavities are often in the ectostroma of the perithecial stromata themselves. The allantoid or beta conidia measure 5–11 × 1–1.5 μ; the dark-brown alpha conidia, 16–40 × 5.5–10 μ.

Single ascospores of *M. thelebola* were isolated from Alnus twigs collected at St. Simeon, Quebec, and sent to the writer by I. L. Connors in September of 1936. The ascospores germinated (Pl. II, Fig. 3) within twenty-four hours, usually by a single stout germ tube, 5 μ in diameter, arising generally from the end, or occasionally from the side, of the spore. Some immature spores, which were still non-septate, also germinated normally. In the course of germination all the spores became pale brown and two- to four-celled.

On oatmeal agar a very scanty surface growth of whitish mycelium is produced. The surface layers of the agar later become blackened, and numerous spheric or confluent, gray-black stromata, 1–4 mm. in diameter, arise. Sections of these stromata show that they are

composed of brownish hyphae and contain many irregular cavities with a slightly differentiated parenchymatic wall. Conidia were formed within these cavities, but they were abnormally distorted. They were pale brown, from one- to four-celled, ovoid to elongate-fusoid, variously bent, curved, or misshapen, and measured 15 42 × 5–10.5 μ.

Autoclaved stems of *Betula alba* were inoculated from single-spore cultures on December 24, 1936. By January 19, 1937, there was formed, where the bark was ruptured, a whitish to gray or slightly yellow-green stromatic mat, which exuded droplets of liquid that were of a brilliant wine color. These droplets contained alpha conidia of the type found on agar and also beta conidia (Pl. II, Fig. 5), which were one-celled, hyaline, ovoid to fusoid or rod-shaped, and 8.5–14.5 × 2–4 μ.

By February 15 more normal conidial pustules developed as numerous papillate swellings, 1–1.5 mm. in diameter, over the entire surface of the twigs. The conidial stromata (Pl. II, Fig. 1) originate in the surface bark layers as spheric to pulvinate masses of hyaline to pale yellow-brown hyphae which grow outward and upward centrifugally in a more or less parallel fashion, pushing up the periderm. Cavities may originate on the lateral surfaces of these stromata, but they remain small and contain only the beta type of conidium. The main, large, flattened or irregular cavities originate in the base of these stromata, and the growing tips of the hyphae above continue to push upward, rupturing the periderm and enlarging the stromata. These cavities have no bounding walls and increase in size and become confluent. Both alpha and beta conidia are formed in them and are exuded in long, threadlike black tendrils. The alpha conidia (Pl. II, Fig. 4) are hyaline and one-celled at first, but soon become pale brown and finally dark brown and usually four-celled, although a few two- or three-celled ones are found. They are generally ellipsoid to oblong, but are often tapered, bent or curved, and measure 23 39 × 5–9 μ. The beta conidia (Pl. II, Fig. 5), which are cylindric, inequilateral or tapered, or allantoid, one-celled, and hyaline, measure 7–9 × 1–1.5 μ, and are formed on more slender conidiophores than are those of the alpha type.

This conidial [1] stage, here definitely shown to belong to the life

[1] Saccardo (*Mich.*, 2 : 542) gives the conidial stage of *M. thelebola* as *Stilbospora thelebola* Sacc. He describes the conidia as straight or curved, three- to five-

cycle of *M. thelebola*, is of a type found associated with the Prosthecium group of the genus Pseudovalsa. *Pseudovalsa stylospora*, for instance, has been shown (8, p. 537) to form similar two- to four-celled alpha conidia within enclosed locules. In this species both ascospores and conidia are hyaline. A similar conidial stage is also reported for *P. macrosperma* by the Tulasnes (7, Pl. 14, Figs. 13–23).

In *M. thelebola*, however, the ascospores have remained two-celled and hyaline, whereas the conidia have become pigmented. This species gives interesting evidence, therefore, of the origin of the Prosthecium type of plant from an ancestor with two-celled hyaline ascospores.

Pseudovalsa Ulmi, nom. nov.

Massariovalsa caudata E. & E., *Proc. Acad. Nat. Sci. Phila.*, 1893: 138 (*non* N. Am. Pyr. 408. 1892).

This species was described under the same name, *Massariovalsa caudata*, in two different places; the two descriptions are based on two different types representing distinct species on different host plants. The first description, which appeared in 1892 (1, p. 408), is based on a collection by Dearness, on Platanus, from London, Ontario. This fungus was issued in Ell. & Ev., N. A. Fung. No. 2928 (a collection made by Dearness in June, 1893). It is the oldest collection of this species on Platanus which the writer has been able to locate, but obviously a fungus collected in 1893 could not be described in 1892. In answer to an inquiry Dr. Dearness stated that the original collection of *M. caudata* (Dearness No. 568) was made on June 26, 1891, and that the 1893 collection was a second one (No. 580). The writer has been unable to locate the 1891 collection, but N. A. Fung. No. 2928 is a typical example of *Pseudovalsa bicornis* (Cke.) Sacc.

The second description under this name appeared in 1893 (2, p. 138). It was based on a collection by Dearness (No. 1901), on Ulmus, from London, Ontario, and is a good species of Pseudovalsa similar to the *P. Berkeleyi* of Europe.

The name *Pseudovalsa* (*Massariovalsa*) *caudata* must be applied to the first description on Platanus, and this becomes a synonym of

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septate, and 32–40 × 10–14 μ. He may have had the conidial stage here described, but his description and figures of spores (Fung. ital., t. 1104) are not characteristic.

P. bicornis (Cke.) Sacc. Since the species found on Ulmus is a good species it must receive a new name. Inasmuch as the name *P. caudata* is preoccupied, the name *Pseudovalsa Ulmi*, nom. nov., is suggested.

This species on Ulmus (Pl. I, Fig. 2) has a very slightly developed, light-colored ectostroma, which is usually obliterated by the erumpent ostioles. The perithecia are circinate and in the unaltered bark cortex. The asci are stout-clavate, 125–150 × 18–35 μ. There are broad bandlike paraphyses in the young perithecia, but these are soon evanescent. The spores (Pl. II, Fig. 7) are oblong-ellipsoid, straight or slightly curved, not constricted at the septa, hyaline, four-celled, 30–45 × 11.5–15 μ, and have a tapered, curved, hamate, hyaline appendage at each end. This structure is typical of the Pseudoprosthecium section. There is a very slight ectostromatic development here, but it is obliterated by the emergent ostioles.

Single ascospores of this species were isolated from twigs of *Ulmus americana*, collected near Whitmore Lake, Michigan, July 20, 1936. This material, which was still immature, was placed in a damp chamber for two days. After twenty-four hours on nutrient agar the matured four-celled spores germinated (Pl. II, Fig. 8) by means of two to four germ tubes, about 5 μ in diameter, arising from any cell of the spore. The immature one-celled spores failed to germinate. The mature spores turned a pale brown during germination.

Growth was fairly rapid on oatmeal agar, forming a white cottony appressed surface growth which changed to a tan or red brown with age. After two to three weeks numerous pulvinate to cylindric grayish stromata, 1 2 mm. in diameter, appeared in these cultures. They consisted of a compacted, parallel, hyaline to yellowish brown mycelium and had irregular pockets or cavities in their outer portions which contained oblong-cylindric, hyaline, four-celled, granular conidia measuring 30–42 × 12.5–14.5 μ.

Autoclaved twigs of *Ulmus americana* were inoculated from single-ascospore cultures on October 27, 1936. Within three weeks numerous erumpent, superficial, grayish, tomentose, pulvinate to cylindric stromata appeared on these twigs. As the twigs dried out more normal pycnidial pustules, which were not strongly erumpent, were formed. The ectostroma of these pycnidia (Pl. II, Fig. 6) arises on the bark surface as a compact mass of upright, parallel hyphae. The central portion of this mass grows upward rapidly and pushes up and eventually ruptures the periderm. The peripheral portions

of the ectostroma do not grow so rapidly and lag behind. This results in the formation of a marginal cavity between the periderm and this thinner portion of the stroma. The free ends of the hyphae bordering this cavity form the hymenium from which the alpha conidia are constricted. These alpha conidia (Pl. II, Fig. 9) are cylindric-ellipsoid or somewhat clavate, straight or slightly curved, hyaline, four-celled, coarsely granular, 37–58 × 12.5–16 μ, and borne on conidiophores of varying length and 1.5–2.5 μ in diameter. Occasional two- or three-celled spores are seen, but they are atypical. The exuded spore masses are pinkish at first, becoming a deep orange later.

In some of the spore masses of older pustules (two months old) a peculiar behavior of the spores was noted. The cells (Pl. III, Figs. 1–2) appear to separate or the protoplasts of the cells round up and are actually expelled from the old walls, which results in four free rounded cells from each spore. The alpha conidia germinate readily from any cell within eighteen to twenty hours, usually by a single germ tube. These fragmented spores and the freed rounded protoplasts germinate equally well (Pl. III, Fig. 3). The fragmented conidia are obovoid to spheroid and measure 12.5–14 × 14–17 μ.

In these twig cultures, after several months' growth, a second type of more irregular, confluent stromatic pustule appeared. These showed no orange spore masses, but merely a minute transparent yellowish droplet which was found to contain a beta type of conidium. The ectostromata of these pustules are more irregularly effuse, flatter, and without the rapidly growing central mass; they have cavities formed either on the surface or within the stromata. What appear to be perithecial primordia were found beneath these stromata. The beta conidia (Pl. II, Fig. 10) are rod-shaped, ellipsoid-oblong, or long fusoid, often tapered toward one end, hyaline, one-celled, and 7–10.5 × 1–2 μ.

A conidial stage found in association with this species on the twigs of the Whitmore Lake collection was very similar to the alpha type of conidial stroma obtained in culture. The conidia collected in the field were 43 × 13–14 μ and formed in shallow cavities on the flanks of an ectostroma.

This conidial stage is likewise typical of those associated with other members of the Prosthecium group. The hyaline, four-celled alpha conidia are here borne on the lateral flanks of the ectostroma,

as in the genus Melanconium, rather than in central cavities, as in *Pseudovalsa stylospora* and *Melanconis thelebola*. These laterally placed cavities may be correlated with the less well developed ectostromata of the Pseudoprosthecium group, but only the establishment of further conidial connections can bear this out.

Melanconis occulta (Fck.) Sacc.

Melanconis occulta represents the extreme type of the Pseudoprosthecium section, in which no ectostroma whatever is produced. The ostioles are fused together and burst through the periderm as a blackened stromatic disc (Pl. I, Fig. 3). The two-celled, hyaline spores have stout, recurved, hyaline appendages (Pl. III, Fig. 4). The peculiarities of its structure have been noted by other writers. On account of the lack of paraphyses Von Höhnel [2] (5, p. 386) placed it in Diaporthe as *D. abnormis* Höhn. There are bandlike evanescent paraphyses in the young perithecium, however, as was pointed out by Petrak (6, p. 97) when he erected the new genus Macrodiaporthe for this species, because of its large spores and limited stroma.

Fuckel (4, p. 190), in his original description, gives a "Cytispora" conidial stage with minute, one-celled, allantoid, hyaline conidia.

Single-ascospore isolations were made of *Melanconis occulta* on November 5, 1936, from twigs of *Populus deltoides* collected near Brighton, Michigan. The spores germinated (Pl. III, Fig. 5) within twenty-four hours by means of one or two germ tubes, 3–4 μ in diameter, arising from either the ends or the sides of the spores. Growth was rather slow on oatmeal agar, and no surface mycelium was formed. A coarse brownish mycelium within the agar turned the surface layers brown and then black, but no fruiting structures have ever been seen on agar.

Autoclaved stems of *Populus deltoides* were inoculated from single-spore cultures on December 24, 1936. There was no visible surface growth upon these twigs until some two months later, when numerous erumpent, elongate ostioles appeared. Sections of the bark made on January 20 showed, however, that there were numerous perithecia developing in the surface layers. Although hundreds of pustules were sectioned, no trace of a conidial stage was ever seen. (In one mount there appeared a number of two- to five-celled, irregular,

[2] Von Höhnel's statement that *Melanconis apocrypta* is this same fungus is incorrect.

fusoid-ellipsoid, brown conidia measuring 17.5–37 × 7–9 μ. These were never seen again, and their origin was not ascertained. Their connection with this species must remain doubtful until further proof is available.)

The development of the perithecial stroma, however, was fairly well determined. The perithecial primordia arise in groups within the bark cortex as spherical knots of mycelium (Pl. III, Fig. 7). These increase in size and later form a stout ostiolar projection on the upper side. At this stage the perithecia appear as a solid mass of very large celled parenchyma, the cells of which are richly filled with large oily droplets. The outer cell layers become dark brown and thick-walled and form a perithecial wall. As the asci develop the central hyaline parenchyma breaks down, and the oily material is used as a food supply for the developing asci. During this development of the perithecium there is a proliferation of hyphae between the surface layers of the bark cortex in a more or less extensive area above the perithecia (Pl. III, Fig. 6) in the region through which the ostiolar necks penetrate. This tissue also becomes a dense, large-celled pseudoparenchyma with dark-brown thickened walls, forming a flat disclike stroma (Pl. III, Fig. 8) just beneath the periderm. The apical hyphae of the ostioles (Pl. III, Fig. 9), which remain hyaline and actively growing, push upward through this plate of tissue and eventually burst through the periderm. This parenchymatic tissue is entostromatic and not ectostromatic, for it contains the remains of the disintegrated bark cells (Pl. III, Fig. 8). The fusion of the ostioles and such entostromatic tissue forms the erumpent disc. The entostromatic tissue is sometimes almost lacking, in which case the ostioles may push through the periderm singly or be fused together and become erumpent in clusters. Before the ostioles push through the periderm, this tissue can be stripped off, which leaves the perithecia in the bark, but after the ostioles emerge the whole perithecial stroma clings persistently to the periderm, which illustrates that it is the ostioles themselves, and not a previously formed ectostroma, which rupture the periderm.

Melanconis occulta has a structure very similar to such Pseudovalsae as *P. hapalocystis* and *P. bicornis*, but more information is needed in regard to the stromatal development of such species to determine whether or not they do form any ectostroma and also the character of their conidial stage, if they possess one. Until this is

known, the apparent absence of a conidial stage and the lack of an ectostroma in *M. occulta* indicate that in this group relationships must be made with some reservations.

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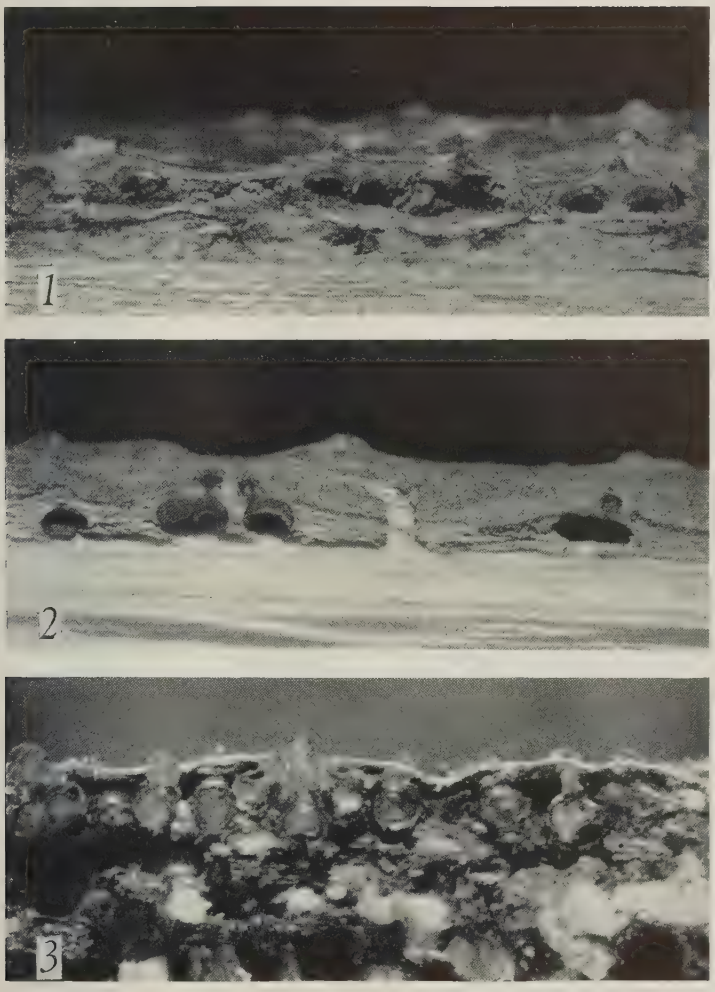
EXPLANATION OF PLATE I

Fig. 1. Radial section of perithecial stromata of *Melanconis thelebola* (Fr.) Sacc. (marginal zones show about the stroma at right)

Fig. 2. Radial section of perithecial stromata of *Pseudovalsa Ulmi*, nom. nov.

Fig. 3. Radial section of perithecial stromata of *Melanconis occulta* (Fck.) Sacc.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EXPLANATION OF PLATE II

Melanconis thelebola (Fr.) Sacc.

FIG. 1. Radial section of conidial ectostromata as formed on twigs of Betula in culture

FIG. 2. Ascospores

FIG. 3. Germinating ascospores

FIG. 4. Alpha type of conidium as formed in culture

FIG. 5. Beta type of conidium as formed in culture

Pseudovalsa Ulmi, nom. nov.

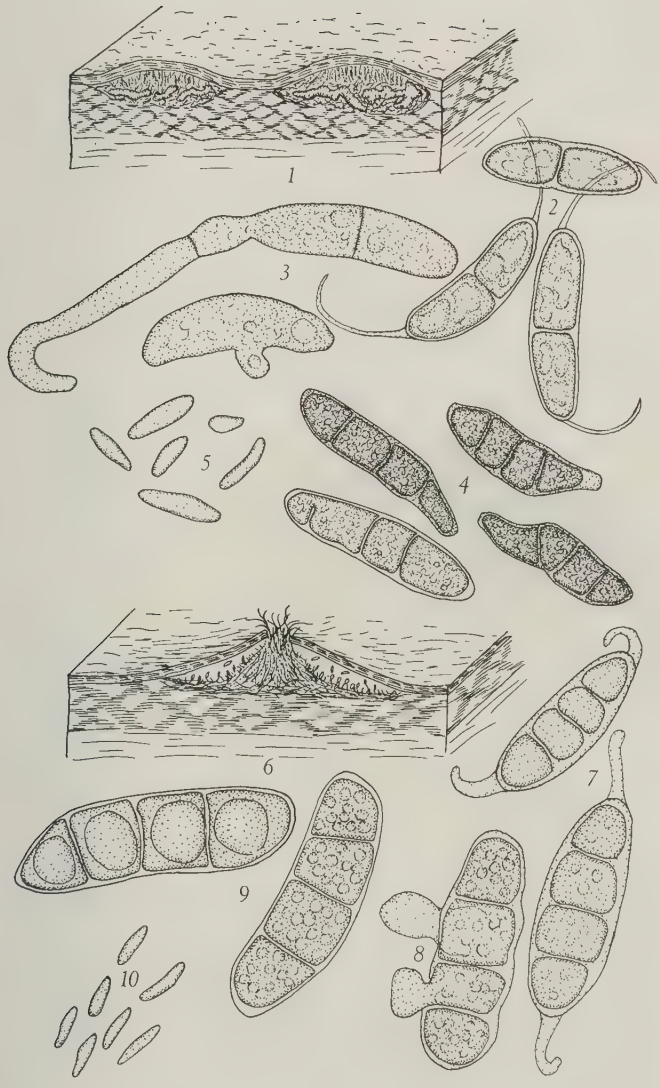
FIG. 6. Radial section of conidial ectostroma as formed in culture on twigs of Ulmus

FIG. 7. Ascospores

FIG. 8. Germinating ascospore

FIG. 9. Alpha type of conidium as produced in culture

FIG. 10. Beta type of conidium as produced in culture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EXPLANATION OF PLATE III

Pseudovalsa Ulmi, nom. nov.

FIGS. 1–2. Fragmentation of conidia (1) and separation of protoplasts of conidia (2), as explained in text

FIG. 3. Germination of fragmented portions and separate protoplasts of the alpha conidia

Melanconis occulta (Fck.) Sacc.

FIG. 4. Ascospores

FIG. 5. Germinating ascospores

FIG. 6. Radial section of a perithecial stroma, showing the stromatic disc formed in the upper bark, above the perithecia, which is penetrated by the ostioles, which in turn rupture the periderm

FIG. 7. Hyaline perithecial primordium with the stromatic disc still poorly developed. Notice separation of periderm

FIG. 8. Thinner section of a perithecial stroma, showing the character of the stromatic disc. Disintegrated bark cells can be seen in this stroma, which indicates its entostromatic nature

FIG. 9. Detail of the apex of one of the erumpent ostioles in Figure 6, showing the hyaline meristematic apex, which has pushed up and ruptured the periderm

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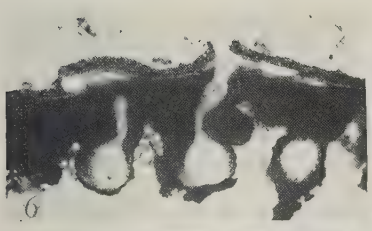
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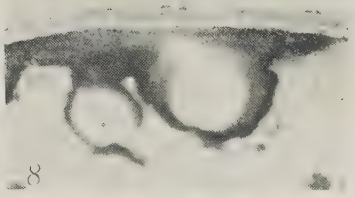
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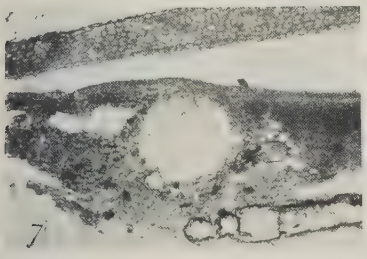
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VEGETATIVE ANATOMY OF THE TOMATO (*LYCOPERSICUM ESCULENTUM* MILL.)

III. DIPLOID AND HAPLOID PLANTS

EDWARD F. WOODCOCK

A SURVEY of the literature concerning the detailed anatomy of the tomato shows few contributions to the information on diploid plants and none on haploid plants. Jorgensen (1), working with diploid plants (chromosome number 24) and triploid plants (chromosome number 36), found that the leaves from the diploid plants differed from those of the triploid plants in the following ways: the leaves from the diploid plants were larger; the number of leaflets was less; and the primary leaflets were much broader. The leaf lamina was thick and a deep green. The triploids were more hairy than the diploids. No observations were made by him on haploid plants.

MATERIAL AND METHODS OF INVESTIGATION

The diploid and haploid plants used for study were growing plants obtained from Gordon Morrison, of the Ferry–Morse Seed Breeding Institute at Rochester, Michigan, who, in 1929, discovered a haploid plant of Marglobe tomato in a breeding culture. A careful observation of the comparative anatomy of the two plants was made to see if there were other differences besides a smaller size and lower vigor of the haploid plant. Cross sections of the stems and various parts of the leaves were cut twelve microns thick and stained with methyl green and Bismarck brown.

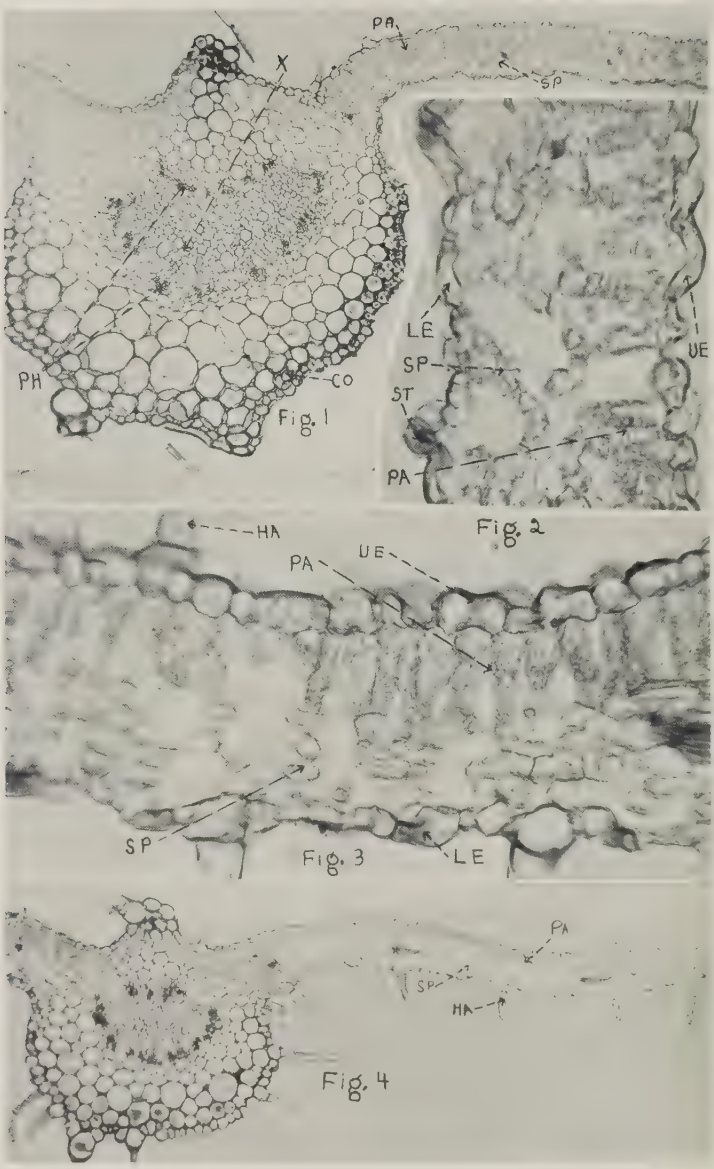
COMPARATIVE ANATOMY OF THE STEMS AND LEAVES

The sections of the stems of the diploid and the haploid plants showed no significant differences in their internal structure and agreed with similar sections of diploid plants already described by the writer (2).

The leaves of the diploid and the haploid plants exhibit some significant differences and some similarities. The leaflets on the haploid plants are narrower than those on the diploid (text Fig. 1). Cross sections through the petiole, rachis, and veins of each reveal that the relative amount and the position of the various tissues are similar and

FIG. 1. A, leaf from haploid plant; B, leaf from diploid plant

agree with the earlier investigations on diploid plants by the writer (3). The cross sections through the leaflets show that the portions between the veins bear a greater number of hairs in the diploid plant (Pl. I, Fig. 4) than in the haploid (Fig. 1). The thickness of this region and the cell structure are approximately the same in both plants (Figs. 2 3). In the diploid plants the upper epidermis is only slightly thicker than the lower and has only a few stomata in it. The lower epidermis has numerous irregularly arranged stomata, whose guard cells are slightly raised above the level of the epidermis.



Lycopersicum esculentum Mill.

SUMMARY

The haploid plant, discovered by Gordon Morrison of the Ferry–Morse Seed Breeding Institute, shows no marked internal anatomical difference from the diploid plants from which the haploid plant arose. The most noticeable external differences are the dwarfed habit of the haploid plant and the smaller number of hairs on the leaf blade.

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EXPLANATION OF PLATE I

(Photomicrographs)

Diploid and haploid *Lycopersicum esculentum* Mill.

Abbreviations: CO, collenchyma; HA, hair; LE, lower epidermis; PA, palisade; PH, phloem; SP, spongy; ST, stoma; UE, upper epidermis; X, xylem.

Fig. 1. Cross section of midvein and blade of leaflet from haploid plant. Only a few hairs appear on the blade. The vascular bundle of the vein region appears crescent-shaped in section, and consists of xylem and phloem in a bicollateral arrangement (× 60)

Fig. 2. Cross section of leaflet blade from haploid plant. Palisade and spongy tissue with their chloroplasts are evident between the two epidermises. Stomata appear elevated above the lower epidermis (× 920)

Fig. 3. Cross section of leaflet blade from diploid plant. Hairs more numerous than on haploid leaf (× 920)

Fig. 4. Cross section of midvein and blade of leaflet from diploid plant. Thickness of blade approximately the same as that of the haploid leaf shown in Figure 1. Hairs more abundant on the diploid leaf than on the haploid (× 60)

THE PENAL ASPECT OF DRUG ADDICTION

MAURICE FLOCH

IN BEGINNING our discussion we might with justification inquire how the drug addict becomes a problem for penology. After all, are we not dealing in his person with a medicopsychological problem rather than with a criminological one? Dr. Healy, one of the truly serious students of human behavior, gives the following description of the effects of morphine, a drug which is rivaled only by heroin as the chief source of addiction:

> Prolonged use of morphine causes (1) a distinct loss of energy. (2) This, as observed in the psychical sphere, appears as a lowering of the powers of attention, self-control and volition. The weakness of the latter frequently is severe enough to be called paralysis of the will. (3) Deterioration of moral judgment and general character. (4) Tendency to morbid impulses of mind and body. (5) Mental vagaries bordering on delusions. (6) Occasional hallucinatory and delusional states. (7) Rarely, well-defined psychoses.[1]

If we take Dr. Healy's description as a basis for our conclusions it would surely appear that drug addiction is primarily a medicopsychological problem. However, when we consider the social concomitants of the habitual use of the narcotics mentioned a different and still more serious aspect opens up before us. The narcotic addict is not, at best, an efficiently functioning unit in a coöperative society. Generally, although there are notable exceptions, his productivity decreases considerably and, as the consumption of the drug proceeds, in time it becomes nil. Many addicts have admitted to the writer that they have found it impossible to control their habits for any appreciable length of time and that they have inevitably succumbed to such excessive use of drugs as would prevent their economic functioning because of the subsequent lethargy. It was the recognition of this fact, of the social disorganization of the habitual user of narcotics, which finally led to the passage of the famous Harrison Narcotic Act by the Congress of the United States and of similar

[1] Healy, William, *The Individual Delinquent* (Boston: Little, Brown & Company, 1927), p. 276.

acts by the various states to control the manufacture and sale of habit-forming narcotics. Contrary to popular belief, however, the penological implications of drug addiction manifest themselves overwhelmingly as a result of the legislation mentioned and only in a very small degree as a direct outcome of criminality arising from the psychological effects of addiction itself.

Necessarily, any laws governing the manufacture, sale, or use of a commodity contain penal provisions designed to punish transgressors. The nature of this type of social act as embodied in legislation itself provides for penological implications. There have always been individuals who either disregard or oppose social will and in this manner become subject to social discipline. In 1935, for example, 1,736 individuals were committed to the various Federal prisons for violation of the Harrison and other narcotic acts. Yet, it must be emphasized at this point, the larger number of those incarcerated in connection with narcotics are convicted for violation of other penal laws, that is, not of those regulating the manufacture, sale, and use of narcotics. How is this to be explained in the light of what has been earlier stated?

Prior to the passage of the Harrison Narcotic Act and similar state acts narcotics were easy to obtain either on prescription by physicians or directly from pharmacies. There were no appreciable limitations. Hence the prices of the drugs were relatively low, within the reach even of individuals in very modest circumstances. Thus one who had become addicted to the use of habit-forming drugs might go on satisfying his craving without difficulty for a long time, at least while he was capable of maintaining a modicum of productivity and earning capacity. Governmental regulation, however, considerably changed the situation. When what has formerly been a free commodity suddenly becomes outlawed for any other than strictly medical purposes, and when the demand for it still exists, that commodity, in the hands of unscrupulous adventurers, assumes the character of a valuable contraband. The prices mount sky-high, only fluctuating in inverse proportion to the success of the enforcement of the prohibitory legislation.

It can easily be seen that under such changed circumstances only the relatively well-to-do addict can maintain without too much difficulty a habit which, according to a study recently engaged in by the writer, costs an average of six dollars a day. The ordinary

workingman addict, whose earning capacity has already been progressively impaired by the addiction, finds himself, therefore, in a quandary. He has either to give up the habit or to obtain money by any means presenting itself, legal or illegal, with which to satisfy it. Thus, since he cannot easily break the habit, in accordance with his particular temperament and the social and physical circumstances surrounding him he becomes either a petty thief or a beggar. We note, then, that the governmental regulation in this sphere is instrumental in bringing about conditions favorable for the formation of a relatively large and parasitical criminal class. It must be remarked, of course, that the foregoing statement is by no means an argument against narcotic laws. The writer is fully aware of the decidedly more dangerous and damaging possibilities of a free and untrammeled sale of habit-forming, demoralizing drugs amid the complex conditions of modern civilization.

What are society's present ways of dealing with the drug addict who is a petty thief or a beggar? In the state of Michigan he is not differentiated for purposes of legal disposition from any other thief or beggar. After arrest he usually appears before judges of the early sessions, is summarily tried, and sentenced to a jail or a workhouse for periods not exceeding ninety days. In the prison, for the first time, some attention is paid, at least from a medical and disciplinary point of view, to his status as a drug addict. To ease his sufferings, which result from an abrupt withdrawal of narcotics, he is subjected to a reduction cure, and a medical régime is subsequently imposed upon him in order to build up his physique. As to discipline and segregation, the addict, owing to his proverbial unreliability, is usually kept under close surveillance. This is a very brief description of the treatment received by the narcotic addict — brief because the process itself lacks any complexity. Bluntly, one might say that nothing fundamental is being done for and with the drug addict who is a thief or a beggar beyond temporary isolation from the larger society and alleviation of his gross physical suffering.

Let us inquire now into the meaning of jail or workhouse incarceration to its subject, the narcotic delinquent. How does he respond to it? What beneficial results accrue to him as a result of society's interference with his life? Does he reform? Does he abandon both his drug habit and his predilection for stealing or

begging? Does he make a new, socially acceptable adjustment because of incarceration? To answer these questions the writer will depend chiefly on his own observations, made over a period of five years, in the Detroit House of Correction.

To be sure, the addict delinquent accepts incarceration with remarkable stoicism. Owing to the relative brevity of the sentences imposed upon him, he views it as a mere incident of his type of existence. The prison of today, after all, is fairly hygienic — at least in the State of Michigan —, offers a more or less acceptable board, and does not subject its inmates to any overly rigorous work routine. Thus it even possesses some elements of superiority as an environment and life schedule in comparison with those enjoyed by most drug addicts when at large, except, of course, that in a well-conducted prison no drugs may be obtained unless prescribed. For the addicts, free life is by no means enviable. As many of them have related to the writer, it is frequently a grueling existence, divided between time spent in stealing or begging enough with which to defray the expenses of the drugs and the lethargy subsequent to the consumption of them. Meanwhile, eating, shelter, and personal hygiene are altogether neglected. That this is a fact is obvious to one who observes drug addicts as they are admitted into the workhouse and notes their generally emaciated, dilapidated appearance. It is not surprising, therefore, that the addict not only accepts incarceration stoically, but — and this must be added — gradually looks upon it as a lifesaver or a prolonger of life, as a form of vacation which is to add zest to future addiction. The latter statement is amply confirmed by the fact that drug addicts often request incarceration from officers of the law with a view to reducing through externally imposed abstinence the overly large quantity of the drug which is required by them and which necessitates excessive stealing. Looking then at the present method of incarceration from this angle, we see that it tends to prolong indefinitely indulgence in drugs.

The question necessarily arises here as to what is to be done. How are the problems of drug addiction and the attendant criminality to be handled? It might also be asked whether or not the prison should continue to serve as an instrument of control. If one were to point out the foremost obstacle in the way of a more successful treatment of addict criminality, one would, for example, direct attention to the framework of present Michigan procedure, that is,

to available legislation. One would note after even a cursory examination of the laws governing such misdemeanors as petty larceny or begging that they are conceived in the spirit of the obsolete philosophy represented by such writers as Jeremy Bentham and Beccaria rather than in the light of the more advanced knowledge gained from the various sciences of human behavior. In the earlier writers the idea of the so-called average man is implied, one who is an independent spiritual entity, making deliberate choices, mainly according to his pleasure, between right and wrong; whose antisocial acts could therefore be stopped merely by opposing to them a quantity of pain commensurate with the pleasure derived from these acts. To deal with this mythical average man, the Michigan legislature empowers the judges to impose the penalty of a fine or a sentence not exceeding ninety days in a jail or a workhouse.

It is easy to see that treatment of this type can have, at best, only fortuitous good results. For we know today, not only through intuition but as a consequence of serious and thoroughgoing studies, that the causes of crimes against property and of other crimes are manifold, and that any single-track, particularistic explanations can lead to nothing but serious error. To refer specifically to the subject of this paper, we are aware of the numerous ways in which people adopt the drug habit and subsequently become violators of property laws. We know that in the processes which finally culminate in crime, the configuration of factors varies, with the physical-constitutional factors playing the dominant rôle sometimes, and the social-cultural or sociopsychological, at other times. An individual who is suffering from a serious malady and becomes on account of it and for other reasons a drug addict and a thief could not be expected to give up his habit unless the important causative agents, such as disease, unemployment, etc., were counteracted in some manner. A mere confinement of such a man to a workhouse for a period not exceeding ninety days would surely represent but an empty gesture. Similarly, no improvement can be anticipated from the short-term incarceration of delinquent addicts whose deviations are attributable to a faulty upbringing in conjunction with a hereditary taint and poor environmental factors, the correction of which is either impossible at the present or would involve years of patient effort.

A fundamental approach to the question of drug-addict criminality requires, above all, a sound legislative foundation. The laws

governing this field of human behavior must be brought into conformity with the tested ideas of the sciences of man before any progress can be made. The judges must be empowered to deal with the person of the drug addict — not with a legal fiction, but with a living human being, complex in make-up, multiple in motivation, and demanding, therefore, careful study and prescription. Specifically, as an initial step, laws must be made with special reference to such criminals as have been proved to be addicted to the use of habit-forming drugs. These laws must have indeterminate sentences, with perhaps a liberal upper limit, five years for instance, for first offenders and no upper limit at all for second, third, and more frequent transgressors. On the other hand, provisions should be made for a judicious employment of the principle of parole, both to safeguard the rights of the individual and to permit some experimentation in a field in which knowledge is as yet far from being definite and organized. Within the framework sketched here, which at least permits time for treatment, a beginning might be made toward a more rational and scientific control of the problem. It is admitted that such legislation might be discriminatory, since it would subject the drug-addict delinquent to a differential treatment in relation to the nonaddict. However, only a thorough recasting of all laws governing misdemeanors would obviate the necessity for special legislation.

Given a sound legal foundation, the next step to consider in the treatment of the drug-addict delinquent is the question of institutional confinement. Obviously, the favorable custodial features of a well-ordered workhouse or prison make it probably the most logical place for this purpose. Nevertheless, we may justly inquire whether even the well-ordered prison is properly equipped at present to undertake the complex task of handling the delinquent drug addict and of curing him of his addiction. After all, mere confinement, as was earlier suggested, will rarely if ever be productive of any fundamental change in his behavior. His deviation must be attacked from many angles. To begin with, he must have a most thorough medical examination, aimed at determining any possible harmful deviation from the constitutional norm. Opportunity must be offered him subsequently to have every defect corrected which might in any manner serve as a source of irritation. This means the necessity for a medical staff composed of a number of specialists and for a properly equipped hospital.

The next logical step would appear to be an attempt to discover the nature and extent of possible personality deviations. Since any given personality trait is always the result of the interaction of biological, social, and psychological factors proper diagnosis and prescription can be made only after a careful study of the individual from all these perspectives; this study necessarily involves the coördinated and coöperative effort of specialists in psychiatry, sociology, and psychology. Still, mere diagnosis of the personality is obviously insufficient. There must follow a carefully planned program of treatment, which might take the form of psychiatric and psychological measures, attitude reconditioning, academic, industrial, and health education, etc. Frequently many or all of these measures combined must be employed to bring about even a modicum of change. However, there are cases in which the personality is so warped that no amount of effort will avail, when the only recourse left is lifelong isolation from society.

It is apparent from this discussion that the prison has a large order to fill if it is to serve as a useful instrument in the attack upon drug-addict delinquency. As yet few prisons can boast of such potentialities in even a fragmentary form. Nevertheless, a very laudable beginning has been made by the United States Government at Lexington, Kentucky, in setting up an institution chiefly for the treatment of drug-addict delinquents. According to the writer's information this institution, in its effort to treat the problem in the light of present-day civilization, employs most weapons tendered by the sciences. If it succeeds, it will be another triumph for those who believe that the real progress of man depends ultimately upon the application of the scientific spirit and method to the problems of human behavior.

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AN ANALYSIS OF FACTORS AFFECTING THE VOLUME OF CURRENCY IN CIRCULATION

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INTRODUCTION

AN ANALYSIS of the factors affecting the volume of currency in circulation may serve to clarify one aspect of the problem of monetary control. If monetary policy is to be employed as an active means of economic regulation, the technical apparatus which governs the money supply must be perfected. This paper is concerned with that problem and not with monetary policy.

The supply of money is composed of deposits subject to check, and hand-to-hand money. In this paper the factors affecting the second of the two components will be considered. An attempt will be made to show that present regulatory devices are poorly suited to control the volume of hand-to-hand money and that their existence makes regulation of the money supply difficult. The principal defect in the present system is that the two types of money bear with unequal pressure upon the reserves. This state of affairs is incompatible with effective control of the volume of money.

Hand-to-hand money, or cash, is the subsidiary rather than the primary form of money. The bulk of payments is accomplished by the transfer of deposits through the use of checks. A residual of payments that cannot be conveniently made in this manner is accomplished by the transfer of paper money and coins. The fact that a bank deposit is a claim upon a bank for cash, so far as the legal rights of the depositor are involved, must not be permitted to obscure the truth that deposits meet the primary test of money, i.e. they are instruments by the transfer of which debt and price contracts are discharged.[1] The control of the supply of money must encompass both cash and deposits. The technical apparatus of

[1] Keynes, John Maynard, *A Treatise on Money* (London, 1930), I : 3; Currie, Lauchlin B., *The Supply and Control of Money in the United States* (Cambridge, Mass., 1934), p. 11.

monetary regulation, however, weights the former very heavily. This state of affairs harks back to the era when hand-to-hand money was the primary form and when the significance of deposits was not recognized.

The function of note issue in a deposit-using country is passive, as will be demonstrated in a later section of this paper.[2] None the less, the conditions under which cash is supplied do not permit passivity. After a treatment of the factors affecting the volume of currency in circulation attention will be given to changes in the present apparatus which would permit more effective control of the supply of money.

INTERRELATION OF CASH AND DEPOSITS

Deposits are one kind of money, cash, the other. The user has the choice of the two forms. The immediate problem is the investigation of the causes which lead to the use of cash. As a starting point, three distinct demands for it may be identified: The general public's demand is of first importance; secondly, there is the demand of the banks, which must be separated sharply from the demand of the general public; finally, there is the demand of foreigners, an element of minor importance, but one which cannot be neglected entirely. Correctly speaking, only cash held by the public is money. That held by the banks is not spent, but is utilized in banking operations,[3] and that of one country held by persons in another country certainly is not money to the first country.

The amount of cash held by the public is the resultant of a vast complex of factors. There are two classes of cash holders, private individuals and business enterprises. Individuals may or may not have bank accounts, but business enterprises normally do. This is an important point, for the utilization of paper money and coins is greatly affected by the relation between the user and the banking system.

The circumstances which determine the holding of money balances by individuals and by business enterprises need not be considered extensively in this paper.[4] All that is of moment here is the

[2] Currie, *op. cit.*, pp. 110–114; Harris, Seymour E., *Twenty Years of Federal Reserve Policy* (Cambridge, Mass., 1933), I: 397–400.

[3] Currie, *op. cit.*, p. 12.

[4] A careful treatment of this topic may be found in Howard S. Ellis, *German Monetary Theory, 1905–33* (Cambridge, Mass., 1934), pp. 69–75.

extent to which money balances are kept in the form of cash rather than in the form of deposits. There is some reason to believe that the percentage of the total which is available in the form of cash is not invariable. The enterprise as well as the individual is obliged to hold more at one time than at another. The enterprise faces irregular receipts of cash, its till-money needs are not constant, and in making up payrolls its holdings must be increased. However, such holdings are generally kept at a minimum because of the risk of theft. The elimination by the Banking Acts of 1933 and 1935 of payment of interest on demand balances removes one incentive to the prompt deposit of cash, although the difficulty of safekeeping is undoubtedly a sufficient motive to prevent its accumulation.

The experience of the past few years has demonstrated that hoarding is of serious consequence to our monetary system. A shift in the public's preference for money in the form of deposits to money in the form of cash is but one aspect of the struggle for liquidity. Cash hoards may be built up in a number of ways, the most common of which is the withdrawal of bank deposits. Only in extremely rare cases would it be expected that bank borrowings would result in hoarding by the borrower directly. The failure of persons to spend cash in the usual fashion may also contribute to hoarding, although there is a presumption that the cash-using group does little hoarding, because of its low economic status. Such hoarding is generally done by those who shift from deposits to cash. The hoarder is unwilling to continue to hold resources in the form of a claim on an institution whose solvency is uncertain, and he converts the claim into a more general form, paper money or even gold. Because of the existence side by side of alternative forms of money, the monetary system has an inherent weakness, and the very device that is supposed to assure public confidence, namely, convertibility, becomes its nemesis.

Hoarding is a purely normative concept. What may be termed normal cash holding can be separated from hoarding only upon an empiric basis. An irreducible minimum of cash holding, also a normative concept, will always be observed. Sudden changes in such holdings, particularly in an upward direction, are a serious matter, because the banking system can supply only a limited amount. At the time of the bank holiday in 1933 the cash holdings of the public were only about 100 per cent greater than in 1930.

The increase which took place between 1930 and 1933 may be called hoarding because there is no evidence that the volume of cash payments increased. The term "hoarding" does not appear to be out of place in this discussion, although its limited significance must not be overlooked.

There is only one way to proceed against cash hoarding, namely, to see to it that the banking system is strong enough to maintain the confidence of the general public. The occasion should never arise for the complete conversion of deposits into hand-to-hand money. Even so, one should note that hoarding presents so grave a problem because of the heavy incidence of cash on the reserves of the member banks as well as upon the reserves of the central bank. When the public shifts from holding a form of money supported by a low reserve to another supported by a high reserve, embarrassment is inevitable. Recent alterations in our monetary system have eliminated the possibility of gold hoarding; and it should be observed that the changes made in the United States are only a further step in the direction in which England and France moved in re-ordering their monetary systems after the War. Certainly effective control of the money supply does not entail gold redemption of hand-to-hand money. The elimination of the option to hold either deposits or cash is not feasible, however.

The approach may now be shifted advantageously from the discussion of balances to the discussion of payments. Some added information on the factors affecting the volume of money in circulation may be obtained by a consideration of the spending of money.

There is no direct method of measuring the relative amounts of payments accomplished by the transfer of deposits and by the transfer of cash. Kinley's estimates, now out of date, are usually extrapolated to give a figure of 90 to 95 per cent of total payments as representing check transactions.[5] Snyder estimated on somewhat different grounds than Kinley that in 1927 some 90 per cent were settled by checks.[6] The exact figure, however, is unimportant.

The residual of payments requires some consideration. One kind

[5] Kinley, David, *The Use of Credit Instruments in Payments in the United States*, National Monetary Commission, 61st Congress, 2d Session, Doc. No. 399 (Washington, 1910); Fisher, Irving, *The Purchasing Power of Money* (New York, 1922), pp. 318, 442–444.

[6] Snyder, Carl, "The Measure of the General Price Level," *The Review of Economic Statistics*, 10 (1928): 40–41.

of transaction involves only one turnover of cash against goods: the cash is withdrawn from the bank, spent, and returned to the bank. There seem to be reasonable grounds for holding that this is the typical pattern. In the other type the money makes repeated turnovers after being withdrawn from the bank. The latter type is characteristic among persons who have no banking connections, and is probably of minor importance. Fisher attempted to estimate the manner in which cash behaves, and concluded that, in 1909, 38 per cent of the cash in circulation made one turnover, 57 per cent made two turnovers, and the remainder, three or more.[7] As Mitchell points out, however, Fisher's estimates involve so large an element of conjecture that they are of doubtful worth.[8]

Burgess has made certain studies of the movement of cash at the Federal Reserve Bank of New York.[9] The volume of cash exhibits several types of short-run fluctuations. There is a rather pronounced weekly movement — cash goes out of the banks in the latter part of the week and returns in the early part of the week. This cycle, Burgess suggests, is to be accounted for by payroll disbursements. Analogous movements are discernible at the middle and the end of the month. Deposits are converted into cash, the cash is spent and returns to the banks. Such transfers represent a shift from one kind of money to another rather than an absolute change in the amount of money. Holidays, especially when they fall on week-ends, cause a temporary upward surge in the amount of cash in use. Presumably individuals withdraw larger amounts than usual from the banks, and merchants, too, supply themselves with larger amounts of change. Holiday demands also represent a shift in the kind of money used.

There are pronounced seasonal movements as well. The high point is reached on the last of December, with a minor peak in June, and the low in January. Whether or not a deposit expansion is called for at the seasonal peaks is a question for monetary theory, but there can be no doubt that additional amounts of hand-to-hand money are needed at certain times of the week, month, and year.

The long-term movement of cash relative to deposits has been investigated by Angell, who found a continuous decline in the ratio in

[7] Fisher, *op. cit.*, p. 474.

[8] Mitchell, Wesley, *Business Cycles, the Problem and Its Setting* (New York, 1927), p. 127.

[9] Burgess, W. Randolph, *The Reserve Banks and the Money Market* (New York and London, 1936), pp. 82–86.

the period from 1890 to 1934.[10] This seems to indicate that a smaller and smaller relative volume of payments is effected by transfers of cash. Angell's ratio provides a verification of the belief that cash is becoming less important. The velocity factor must be taken into account, but, unfortunately, there are no satisfactory data on this matter.

There is some reason to believe that in the past few years there has been a shift away from checks to the use of cash. The elimination of many banks has reduced banking facilities and thus caused a number of people to use cash instead of checks and to hold larger amounts of cash. With fewer banks, cash is less easily obtained by withdrawal of deposits, and accumulations of it are deposited less frequently. The lack of convenient banking offices became so serious in Chicago in 1934 that money-changing establishments flourished.

Another factor that has operated to discourage the use of checks has been the general practice by the banks of applying service charges and enforcing minimum balances. The small checking account is definitely discouraged. In the struggle for increased earnings the banks have endeavored to transfer costs to depositors. Some appreciation of the magnitude of these charges may be obtained from studies of bank earnings. Such fragmentary data as are available justify the inference that banks have increased their income by the use of service and exchange charges.[11]

A third factor of some importance is the extent to which local governmental bodies are obliged to hold cash because of statutory requirements as to receipt of interest upon deposits. This point has been referred to by the Federal Reserve authorities, but they have presented no specific data.[12] It seems reasonable to believe that cash holding by governmental units is a transitory phenomenon and that it will disappear as existing legal requirements are modified to allow deposit of funds at lower or zero rates of interest.

When we turn from the demand of the general public to the demand of the banks, a different set of factors must be considered.

[10] Angell, James W., *The Behavior of Money* (New York and London, 1936), pp. 18–20.

[11] *Annual Report of the Board of Governors of the Federal Reserve System for 1935*, p. 158; *Annual Report of the Federal Deposit Insurance Corporation for 1935*, pp. 198–200.

[12] *Annual Report of the Board of Governors of the Federal Reserve System for 1935*, p. 25.

The published data on money in circulation lump together the holdings of the general public and of the banks, which is unfortunate. The reason for reporting the data in this form appears to be that the holdings of the Treasury and Federal Reserve banks are readily available, whereas the holdings of the member and nonmember banks are obtainable only for call dates. Various investigators, by subtracting vault cash of reporting banks from money in circulation, have constructed series showing the cash holdings of the public.[13] The most elaborate of these is that of Angell, who has built up a monthly series by estimating vault cash holdings for intercall dates. This series is of only limited usefulness because of its method of derivation. For the purposes of this paper the data are not of importance, and little weight need be placed on the quantitative material.

EFFECT OF VARIATIONS IN CASH UPON BANK RESERVES

As is generally known, member banks are not permitted to count cash in vault as legal reserves, which, under present laws, must consist of free balances with Federal Reserve banks. The vault cash of member banks therefore consists only of till money and is ordinarily kept at a minimum consistent with the day-to-day needs of the bank. Since the Federal Reserve banks bear the cost of transporting cash, the member bank is enabled to ship all excessive amounts to its Reserve bank and to maintain its legal reserves at a maximum. During the 1920's the member banks were able to reduce vault cash to a small percentage of deposits, as the Committee on Member Bank Reserves of the Federal Reserve Board observed.[14] There is actually no reason why vault cash should not be included in legal reserves. In fact, those member banks which are located at some distance from Federal Reserve banks and branches are discriminated against.[15]

The vault cash of a bank serves to meet the withdrawals of depositors, to supply change to customers, especially retail merchants, and to negotiate items for nondepositing customers. In most centers clearing-house balances are no longer settled in cash directly. The

[13] Fisher, *op. cit.*, pp. 432–444; Currie, *op. cit.*, pp. 29–33; Angell, *op. cit.*, pp. 175–181.

[14] *Member Bank Reserves, Report of the Committee on Bank Reserves of the Federal Reserve System* (1931), pp. 10–14.

[15] *Ibid.*, pp. 13, 22–23.

vault cash of the banks is to all intents and purposes the means through which deposits are converted into hand-to-hand money.

In periods when excess reserves are at a minimum the banks hold no more vault cash than is absolutely necessary. When excess reserves are large, banks may allow vault holdings to increase. In 1929, for example, vault cash of member banks stood at 1.5 per cent of deposits, but in 1936 had increased to slightly over 2 per cent.[16] One should note with reference to the problem of excess reserves that the reduction of the ratio to the old figure will contribute between 100 and 200 million dollars of additional reserves. Member banks were able to reduce vault cash from 3.5 per cent of net deposits in 1918 to 1.5 per cent in 1929, and a similar development may be expected in the future.[17]

As the system is now constituted, increases and decreases of vault cash cause exactly inverse changes in the legal-reserve position of the banks. There is no reason why the disposition of the management of the individual bank to hold more or less vault cash should affect the reserve position of the banking system. The present requirement was adopted in 1917 to force member banks to deposit gold in the Federal Reserve banks, and that end has long since been achieved. Vault cash should properly be included in legal reserves.

The final point to be considered is the timing of increases and decreases in the volume of money in circulation relative to other variables. A net increase in the volume of deposits is frequently held to be followed after some interval by an increase of money in circulation.[18] The analysis runs in this fashion: The banks make additional loans, the borrowers taking the proceeds in the form of deposits; subsequently the goods are placed upon the market in the sphere where cash is used, and added hand-to-hand money is required; at the peak of the expansion there occurs an "internal drain" on the banks, to use Hawtrey's phrase.[19] This sequence leads to the position, adopted by the Federal Reserve Board,[20] that control

[16] *Annual Report of the Board of Governors of the Federal Reserve System for 1935*, p. 134.

[17] For a comparison of vault cash to cash in the hands of the public see Angell, *op. cit.*, pp. 14–15.

[18] Edie, Lionel D., *Money, Bank Credit and Prices* (New York and London, 1928), pp. 171–173; Bradford, F. A., *Money and Banking* (New York and London, 1935), pp. 419–420.

[19] Hawtrey, R. G., *Currency and Credit* (New York and London, 1919), pp. 20–23.

[20] Harris, *op. cit.*, p. 399.

should be exercised over deposits rather than over note issue directly. Empirical verification of the sequence is to be found in the immediate postwar boom.[21] Strictly speaking, this kind of sequence will be observed only if the multiple expansion of deposits arises out of the granting of working-capital loans, which may explain why the lag is not observed in the 1928–29 period, when commercial loans had in a large measure been replaced by other types of bank assets.

Angell's work on this phase of the problem shows that there is no ground for holding that outside currency follows any definite pattern with regard to deposits, wholesale prices, retail prices, department store sales, and payrolls. In fact, there is little evidence that the volume of cash held by the general public during the period from 1923 to 1930 behaved in definite relation to any other series indicative of business activity.[22] Another point of some significance raised by Angell is that, on a monthly basis, cash held by the public and the circulating deposits do not fluctuate inversely.[23] On the whole, they tend to move together, increasing and decreasing at the same time. A precisely inverse relationship would be required if the supply of money were to be held constant. As the monetary system is now constituted, this end cannot be achieved.

Enough is known of the behavior of deposits and cash to lead to the conclusion that the general public's and the bank's demands for cash are not constant. Under the Federal Reserve System a mechanism has been provided by which the volume of paper money can be increased and decreased in accordance with the demands of cash users. There can be no question that this is a technical improvement over the national banking system. A member bank can supply additional cash to the public by drawing upon its Federal Reserve bank. A loss of legal reserves results; it may be compensated for by the member bank's borrowing at the Reserve bank. Actually this seems to have been the usual procedure, for money in circulation and borrowings exhibit similar movements.[24]

A general question may be raised at this point as to whether or not the mechanism of the Federal Reserve System is a satisfactory method of supplying additional cash. An increase in the public's

[21] Edie, *op. cit.*, p. 159.
[22] Angell, *op. cit.*, p. 56.
[23] *Ibid.*, pp. 37, 59.
[24] Burgess, *op. cit.*, pp. 78–79; Goldenweiser, E. A., *The Federal Reserve System in Operation* (New York, 1925), p. 67.

demands for cash forces member banks into debt unless member-bank reserves are increased in some other way, e.g. by gold imports, open market operations, or Treasury disbursements. Increases in member-bank borrowings tend to cause a tightening of the money market, as has been demonstrated by Riefler.[25] If the shift by the public from deposits to cash is interpreted as a change in the composition of the money supply, there seems to be little reason why money rates should be subjected to any pressure. That they tend to be is merely an accident developing out of the fact that cash trenches more deeply into reserves than do deposits.

There is an important problem involved in member-bank borrowing. The control of the volume of member-bank reserves is vitiated by permitting member banks to borrow at the Reserve banks.[26] At the outset the issuance of Federal Reserve notes was linked closely to borrowing, but the connection has been largely severed by administrative and legal changes.[27] The vestigial elements of the original devices do not provide elasticity of note issue. Although the present methods allow variations in the volume of paper money, they do not permit these variations to take place without marked effects upon the reserves of the banking system. The control of the supply of money is therefore rendered awkward. In this connection the large increase in the cash holding of the public which has taken place in the past four years serves as an excellent illustration. The amount of cash held by the public is now larger than ever before. Fortunately this increase in the volume of money in circulation has come at a time when the banks have had large excess reserves, so that member banks have not been obliged to borrow to maintain their reserve position. This is in sharp contrast to the situation in the final quarter of 1931, when the loss of reserves induced by gold outflow and cash withdrawal caused a severe contraction of deposits.

Other things being equal, an increase in the cash holdings of the public tends to force a multiple contraction of deposits. The depositor withdraws cash, releasing the bank from the necessity of maintaining a legal reserve against the now extinct deposit. The

[25] Riefler, W. W., *Money Rates and Money Markets in the United States* (New York and London, 1930), pp. 27–30.

[26] Currie, *op. cit.*, p. 182.

[27] Simmons, E. C., "Elasticity of the Federal Reserve Note," *American Economic Review*, 26 (1936) : 683–690.

decline in deposits, however, releases only a fraction of the reserves needed to supply the cash. The bank's vault cash is depleted, and it must secure cash either by borrowing or by disposing of assets. Its borrowings will be temporary in any case, so that a sale of assets will result eventually, with a consequent multiple contraction of deposits. Only if some additional bank reserves appear at the opportune time is the tendency arrested.

Similarly, a reduction in the cash holding of the public tends to cause a multiple expansion of deposits. Unless member-bank reserves are reduced at such a time, an expansion of the supply of money will result from a change in the composition of the supply.

An examination of the factors affecting the volume of money in circulation, or, in other words, of the cash holdings of the public and of the banks, does not reveal any reason for focusing monetary control upon cash rather than upon deposits. The public holds more or less cash as a matter of convenience. The banks hold more or less cash in accordance with the needs of the public and the volume of legal reserves. Changes in the relative amounts of cash and deposits are to be explained by changes in the public's preference for alternative forms of money. A well-designed monetary system should be able to supply the public with either cash or deposits in accordance with the public's preference. The total amount of both forms should be determined by monetary policy.

COMPENSATORY ACTION BY THE CENTRAL BANK

The monetary system of the United States is so constructed that control over the total supply of money is difficult. It must be exercised by means of the volume of reserves of both member banks and Federal Reserve banks. The fact that changes in cash bear directly on reserves and changes in deposits bear upon reserves only through a system of leverages results in a differential incidence. Under the present system an increase in the cash holding of the public tends to force a multiple contraction of deposits, and vice versa. This situation is illogical. Its existence is to be explained only in terms of the historical evolution of monetary institutions. Fundamentally, it reflects the belief that deposits are "credit" rather than money, a conception which might profitably be abandoned.

Before we conclude this discussion some consideration should be given to the interrelation of the member banks, the Federal Reserve

banks, and the Treasury, which is in itself a central banking institution.

The problem is complicated by the fact that cash is supplied by the Treasury and by the Reserve banks to the member banks, which in turn supply the public. Almost by accident, it seems, the supplying of minor and subsidiary coins creates member-bank reserves as the public's withdrawals of these coins from the banks reduce those reserves. The Treasury buys the metal to manufacture the coins, and so depletes its balances at the Reserve banks; when the coins are minted they are shipped to the Reserve banks, which automatically increases the Treasury's balance. Unless the Treasury maintains its balance at the new figure, which is unlikely, the member banks are automatically provided with additional reserves. Supplying the public with newly minted coins is thus accomplished without a tendency toward multiple contraction of deposits.

An analogous case is the issue of silver certificates. The Treasury buys silver, drawing down its balance at the Reserve banks initially, but increasing it subsequently by paying over silver certificates to them. These certificates are shipped in turn to the member banks and paid out to the public as paper money is withdrawn. Additional member-bank reserves are created. There is one sharp difference between coin manufacture and silver-certificate issuance. The former is adjusted to the estimated needs of the public, whereas the latter is under a mandate from Congress.

When cash is supplied from the "other cash" of the Federal Reserve banks without any change in the amount of Treasury issues, a depletion of the reserves both of the Federal Reserve banks and of the member banks occurs. If the cash consists of Federal Reserve notes, the Federal Reserve banks do not lose reserves, for there is merely a tying-up of gold-certificate reserves. Member banks draw down their deposits, releasing the 35 per cent reserve in the form of gold certificates or lawful money or both held against them, and take notes, against which a minimum reserve of 40 per cent in gold certificates must be maintained. Here again the differential reserve requirement operates. The minimum is 5 per cent, but normally the differential is greater because of the necessity of employing more than a 40 per cent gold-certificate reserve behind Federal Reserve notes.

An increase in the cash holding of the public thus has several possible effects upon the reserve position of the member banks and

of the Reserve banks. If Treasury currency increases at the same time, member-bank and Reserve-bank reserves are left unchanged. If the Reserve banks furnish the cash from their other cash, member-bank reserves decline and Reserve-bank reserves decline. If Federal Reserve notes are taken, member-bank reserves fall, but Reserve-bank reserves are unchanged in amount, although an increased number of gold certificates is tied up.

In none of these cases need member-bank reserves decline, provided the member banks borrow to obtain the required cash. In fact, they may increase by more than the cash withdrawals in the cases where the Treasury supplies additional cash to the Reserve banks.

The central banking authorities can forestall incidence of changes on member-bank reserves through open-market operations, and thus prevent the money market from being affected by the behavior of cash. As cash flows into the hands of the public, open-market purchases could be used to restore member-bank reserves and to offset the tendency of member-bank borrowing. Similarly, in the event of a decline in the cash holding of the public, open-market operations could be used to reduce member-bank reserves. This type of action would seem to be called for if the Treasury were passive. Open-market operations on a somewhat smaller scale than cash movements would be warranted because the purpose would be to maintain that volume of reserves which would permit deposits to increase or decrease by the same amount as cash decreased or increased. The judicious use of open-market operations could serve to compensate for losses and gains in member-bank reserves caused by changes in the amount of circulating cash.

The reserves of the Reserve banks, however, would not be relieved of the incidence of changes in such cash. A reduction in the gold-certificate reserve behind Federal Reserve notes to the same percentage as the reserve against deposits in member banks would partly accomplish this end. By obliging the Reserve banks to maintain only 35 per cent of 14, 20, or 26 per cent coverage, as is the case with deposits, or approximately 7 per cent on an average basis, an increase in Federal Reserve note circulation could be made to have the same effect as an increase in member-bank deposits.

Another line of attack would be to have the Treasury supply all cash to the Reserve banks, i.e. both coins and paper money.

The Reserve banks would call upon the Treasury to meet the demands of the member banks, which in turn would supply the public. A reduction in the public's holdings would flow to the Reserve banks and thence to the Treasury. The Reserve banks would control the reserves of the member banks by open-market operations. This scheme is visionary, to say the least, but it would remove some of the present defects.

Another possible plan consists in having the individual member banks issue the paper money, the notes being backed by the same reserve as deposits. Coins might continue to be supplied as at present, for with appropriate open-market operations the effects of changes could be compensated. For obvious reasons, the trend does not appear to be in this direction. There is no need to dwell upon the cumbersomeness of such an arrangement. In short, it involves a return to the national banking system.

Finally, there is the ideal solution, namely, the adoption of the "100% plan." [28] Under this plan there would be no reserve leverages within the monetary system. Cash and deposits would move inversely, and changes of the composition of the money supply would not induce changes in the supply. The "100% plan" eliminates not only multiple expansion of deposits but also the differentials in the incidence of different types of money upon reserves.

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[28] Simons, Henry C., *A Positive Program for Laissez-Faire* (Chicago, 1934), pp. 23–26; Currie, *op. cit.*, pp. 151–156; Fisher, Irving, *100% Money* (New York, 1935).

PUBLIC-UTILITY VALUATION SINCE 1929

C. EMERY TROXEL

TO COMMENCE a summary and an appraisal of recent developments of the moot and perennial problem of public-utility valuation one cannot do better than to quote these recent incisive comments of Mr. Justice Stone:[1]

> In assuming the task of determining judicially the present fair replacement value of the vast properties of public utilities, courts have been projected into the most speculative undertaking imposed upon them in the entire history of English jurisprudence. . . . When we arrive at a theoretical value based upon . . . uncertain and fugitive data we gain at best only an illusory certainty.

During a severe depression seemingly unnecessary legal entanglements which enmesh public-utility regulation are most noticeable. If appeals and retrials may be avoided, it is a fortunate and able commission which may consummate in one year a fairly thorough rate investigation of a sizable system. With court appeals prolonged investigations of from five to ten years are not uncommon. Thus during a depression prolongation of an investigation for as much as one year, not to mention a five-year period, may result in a meaningless decision, because price, cost, and income conditions have so changed in the meantime that a new investigation is warranted. To the protracted juristic "fair"-valuation process may be attributed much of the slowness of regulation and the infrequency of investigations. When a commission must obtain a costly detailed engineering appraisal of reproduction cost and thereafter combine this valuation in some legally undefined manner with other but unrelated valuation elements to form the fair-value fusion, no commission may effectively investigate more than a few companies each year. The recent sharp decline of prices — the first since state regulation of gas, electric, and telephone utilities has been attempted — should have aroused jurists from their apathetic belief that cost of reproduction, the justification of the use of which assumes increasing prices, is a proper valuation ingredient.

[1] *West v. Chesapeake & Potomac Telephone Co.*, 295 U. S. 662 (1935).

Consequently commission and court opinion on public-utility valuation in depression environment will be observed and briefly appraised. First, recent opinions on the content and determination of fair value will be surveyed. Then a new development, the use of price indices for measurement of reproduction cost or fair value, will be observed. And, finally, revision of opinion on going value will be recounted.

I

Since 1929 the United States Supreme Court has considered methods of measuring public-utility valuation in two leading decisions. In neither of these decisions is there a hopeful sign of relaxation of the Court on its aged valuation doctrines. Nor is there any indication that economic arguments have pierced the apparently impenetrable legal bulwarks which so long have confined the valuation step of the rate-fixation process. And, still more significant, there is as yet no consideration by the Court of the goal of effective utility regulation, which has been impeded by the valuation "bottle-neck."

When the Los Angeles Gas and Electric Corporation decision was given in 1933 some students of business regulation believed the Court would not long be "wallowing in this historic muck." [2] Perhaps their expectations were too much founded on Mr. Justice Pierce Butler's lone dissent. And yet the California Railroad Commission's fair-value figure of $65,000,000, which was only $5,000,000 more than cost, was upheld by the Court. As judged, however, on the following excerpt from the opinion, the Court altered scarcely any of its forty-year-old valuation generalities: [3] "An honest and intelligent forecast of probable future values, made upon a view of all the relevant circumstances, is essential."

Denying that it had "departed from principles announced in earlier cases," the Court reiterated that its "duty . . . is merely to ascertain whether the legislative process has resulted in confiscation." [4] Consequently, the Court's most recent treatment of basic

[2] Glaeser, Martin G., "The Supreme Court Sheds More Light upon the Doctrine of Fair Value," *Journal of Land and Public Utility Economics*, 11 (1935): 316.

[3] *Los Angeles Gas & Elec. Corp. v. R. R. Comm. of California*, 289 U. S. 287 (1933). See also *Clark's Ferry Bridge Co. v. Pub. Serv. Comm. of Pennsylvania*, 291 U. S. 227 (1934).

[4] *West v. Chesapeake & Potomac Telephone Co.*, 295 U. S. 662 (1935).

valuation requisites in the Los Angeles Gas and Electric Corporation and the Chesapeake and Potomac Telephone Company cases indicates continuance of the utility-valuation mixture of unrelated data. Indeed, the Court has advanced but little in analysis of the valuation problem since the *Smyth v. Ames* decision.[5] The following excerpt from the Chesapeake and Potomac Telephone Company opinion reveals the almighty importance of the *Smyth v. Ames* decision:[6]

> . . . the amount of that investment is to be considered along with the property as presently existing, in order to arrive at a fair conclusion as to the present value, for actual cost, reproduction cost and all other elements affecting value are to be given their proper weight in the final conclusion.

The idea of an "intelligent forecast of probable future values" in earlier Supreme Court decisions has been expanded in the Chesapeake and Potomac Company case to this more explicit, but probably more disturbing, conclusion:[7]

> It is true that any just valuation must take into account changes in the *level* of prices. . . . While . . . the owner of such property must assume and may not pass on to the public the risk involved in a general decline in values, and may have the advantage also of a general rise in such values, it would not only be unfair but impracticable to adjust the value . . . to *sudden fluctuations* in the price level. . . . A public service corporation ought not . . . be permitted to claim to the last dollar an increased value consequent upon a sudden and precipitate rise in spot prices of material and labor. No more ought the value . . . be depressed by a similar sudden decline in the price level. [*Italics supplied.*]

If the requisite of forecasting the trend of prices has always revealed the Court's unfamiliarity with economic affairs, so much more do these comments on "sudden fluctuations" of prices reveal a lack of understanding. Obviously public-utility valuations are not to be changed each month, because the commission form of regulation does not entail frequent investigations. It seems proper, nevertheless, to use "spot" prices, rather than some average of prices to eliminate sudden fluctuations of prices, in calculating cost of reproduction as a step in determination of eclectic fair value. Or, to put the criticism

[5] 169 U. S. 466 (1898).

[6] See n. 4. Mr. Justices Stone and Cardozo, in *St. Joseph Stock Yards Co. v. U. S.*, 289 U. S. 38 (1936), assert that the "doctrine of *stare decisis*, however appropriate and necessary at times, has only a limited application in the field of constitutional law."

[7] *West v. Chesapeake & Potomac Telephone Co.*, 295 U. S. 662 (1935).

otherwise, there are no rules or means of measuring how many years' average of prices will satisfy this requirement. Who will contend that "normal" prices may be forecast?

Secondly, the Court may, without recognizing its path, be veering toward use of the prudent-investment or original-cost measure. If in eliminating sudden fluctuations of prices a long enough period of prices is used to obtain the average, prudent investment and estimates of cost of reproduction may be so similar that it will be unimportant which one is accepted for the rate base.

Finally, the Supreme Court awaited depression years, when company claims for cost of reproduction were much reduced, to emphasize the need for "average" rather than spot prices in calculating cost of reproduction. The dissenters in this case observed through Mr. Justice Stone that [8]

> For a period of twenty years or more of rising prices, commissions and courts, including this one, have regarded price variations as persuasive evidence that present fair value was more than cost. I see no reason for concluding that they are of less weight in times of declining prices.

To judge from the variety of decisions, state commissions and lower courts have not been able to decipher the verbiage of the Supreme Court on public-utility valuation. Some commissions had fixed fair value considerably above original cost; others believed that original cost or less was a fair value during depression years. A number of commissions gave consideration to the sharp decline of construction costs; while others dismissed the influence of price trends, a factor that has been emphasized by the Supreme Court. A few commissions chose spot prices to measure cost of reproduction, whereas others selected an average of a varying number of years of prices in calculating reproduction cost.

Generally, state commissions have not digressed far from Supreme Court declarations on valuation. Some of these commission opinions since 1929 indicate implicit willingness to endeavor to follow the Court.[9] They believe that a regulated company's rate base "is

[8] *West v. Chesapeake & Potomac Telephone Co.*, 295 U. S. 662 (1935).

[9] *Re Indiana Service Corp.* (Ind.), P. U. R., 1930E, 278; *Re Tennessee Elec. Pr. Co.* (Tenn.), P. U. R., 1930E, 312; *Pub. Util. Commissioners of New Jersey v. Elizabethtown Water Co.* (U. S. Cir. Ct.), P. U. R., 1930E, 373; *Re Ohio Bell Telephone Co.* (Ohio), P. U. R., 1931B, 46; *St. Louis v. Pub. Serv. Comm.* (Mo.), P. U. R. 1931B, 448; *Re Black River Telephone Co.* (N. Y.), P. U. R., 1931C, 26; *Elko v. Elko-Lamoille Pr. Co.* (Nev.), P. U. R., 1931C, 14; *Re Alexandria Water*

not the result of consideration of any one element" [10] and that rate cases should not be put in a "straight jacket of rules"; [11] rather, fair value should be based on a "reasonable judgment . . . of relevant facts." [12] In several depression-time rate cases the California Commission was content to follow the Supreme Court and, indeed, to insist that its valuation doctrines be followed because the fall of construction costs frequently made possible fixation of fair value equal to or less than prudent investment. To this Commission, which has long preferred use of prudent-investment measurement of the rate base,[13] it was not conceivable that property "80% of which has been constructed in the high-price period following 1919, could not be reproduced for a lesser cost under prices prevailing in . . . 1933." [14] Other commissions, although there was an avowed adherence to Supreme Court decisions, placed fair value below reproduction cost or based it on historical cost, which approximated cost of reproduction.[15]

Declining prices in the depression afforded several commissions an opportunity to depart from the valuation mixture of the Supreme

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Co. (Va.), P. U. R., 1932C, 342; *Scranton-Spring Brook Water Serv. Co. v. Pub. Serv. Comm.* (Pa. Superior Ct.), P. U. R., 1932C, 471; *Re Potomac Edison Co.* (Md.), P. U. R., 1933B, 6; *Re Broad River Pr. Co.* (S. Car.), P. U. R., 1933C, 351; *Illinois Commerce Comm. v. Pub. Serv. Co. of Nor. Ill.*, 4 P. U. R. (N. S.), 1 (1934); *Dept. of Pub. Works v. Washington Water Pr. Co.* (Wash.), 4 P. U. R. (N. S.), 363 (1934); *Re Home Gas & Elec. Co.* (Colo.), 5 P. U. R. (N. S.), 107 (1934); *Blytheville v. Blytheville Water Co.* (Ark.), 15 P. U. R. (N. S.), 177 (1936).

[10] *Elko v. Elko-Lamoille Pr. Co.* (Nev.), P. U. R., 1931C, 14.

[11] *Re Home Gas & Elec. Co.* (Colo.), 5 P. U. R. (N. S.), 107 (1934).

[12] *Blytheville v. Blytheville Water Co.* (Ark.), 15 P. U. R. (N. S.), 177 (1936).

[13] Wherever the California Railroad Commission has been able to find adequate cost data, prudent investment has served as the lone or principal measure of fair value. To appease the regulated companies and to limit numerous court controversies, a return has usually been allowed in excess of a fair return measured on cost. *Re Los Angeles Gas & Elec. Corp.* (Cal.), P. U. R., 1931A, 132; *Fresno Traction Co. v. San Joaquin Lt. & Pr. Corp.* (Cal.), P. U. R., 1932D, 310.

[14] *Re Pacific Gas & Elec. Co.* (Cal.), 1 P. U. R. (N. S.), 1 (1933). See also *California Farm Bureau Fed. v. San Joaquin Lt. & Pr. Corp.* (Cal.), P. U. R., 1932D, 310; *Los Angeles v. Sou. Cal. Telephone Co.* (Cal.), 14 P. U. R. (N. S.), 252 (1936); *San Diego v. San Diego Consol. Gas & Elec. Co.* (Cal.), 7 P. U. R. (N. S.), 443 (1935).

[15] *Re Augusta Light & Telephone Co.* (Wis.), P. U. R., 1933B, 478; *Re Lone Star Gas Co.* (Okla.), P. U. R., 1933C, 1; *Pub. Serv. Comm. of Missouri v. East Missouri Pr. Co.*, P. U. R., 1933E, 388; *Re Southern Bell Telephone Co.* (Okla.), 16 P. U. R. (N. S.), 1 (1936).

Court. In the light of falling prices the Oregon Commission believed that "prudent-investment theory is afforded additional weight and value by the fact that . . . a substantial portion of [the] plant [was installed] during the past ten years when prices were somewhat above a normal level." [16] The Maryland Public Service Commission, which was rebuked in the Chesapeake and Potomac Telephone case,[17] asserted that "the importance of original cost is enhanced" because of inability to obtain adequate prices to enable it to measure reproduction cost.[18] Another commission, which regards the valuation generalizations of the Supreme Court as "arbitrary and capricious," permitted what is "substantially the prudent investment" to be the controlling valuation factor.[19]

In 1933 the Wisconsin Public Service Commission anticipated and even extended the Supreme Court's view that public-utility valuation should not be affected by sudden fluctuations of prices,[20] when it concluded that [21]

> A time of business stagnation, of ruinously low prices and "subsistence" labor rates, of rapidly fluctuating prices and values is not the time to call upon this Commission to base rates upon a fair value, and thus defeat the Commission's desire and, indeed, its duty to preserve the stability of this essential business. We have an obligation to the investors in this property, and until specifically directed by the courts we decline to proceed upon the basis of a fair value of the property under present conditions.

Determination of fair value should not be restricted to recovery and boom times. If reproduction costs shall be given weight only in prosperous economic environment, the fair-value concept is a misnomer which impedes realization of rate reductions.

In conformity with the Supreme Court's belief that the trend of prices must be examined,[22] because of the necessity of forecasting future rate bases, state commissions in recent decisions have generally admitted giving consideration to apparent price trends when cost of

[16] *Re Portland Elec. Pr. Co.* (Ore.), P. U. R., 1930D, 357.

[17] 295 U. S. 662 (1935).

[18] *Re Conowingo Pr. Co.* (Md.), 10 P. U. R. (N. S.), 353 (1935).

[19] *Dept. of Pub. Serv. v. Grays Harbor Ry. & Lt. Co.* (Wash.), 12 P. U. R. (N. S.), 178 (1936). See also *Re Northern States Pr. Co.* (N. Dak.), 15 P. U. R. (N. S.), 126 (1936).

[20] *West v. Chesapeake & Potomac Telephone Co.*, 295 U. S. 662 (1935).

[21] *Re Wisconsin Telephone Co.* (Wis.), P. U. R., 1933B, 412.

[22] *St. Louis & O'Fallon Ry. Co. v. U. S.*, 279 U. S. 461 (1928); *Clark's Ferry Bridge Co. v. Pub. Serv. Comm. of Pa.*, 291 U. S. 227 (1932); *Los Angeles Gas & Elec. Corp. v. R. R. Comm. of California*, 289 U. S. 287 (1933).

reproduction is determined.[23] Possibly some of the commissions were rendering "lip service" to the Supreme Court's wishes. In any event, it should be enough to ask a state commission to synthesize unrelated valuations into a fair value. Unless they are seers of economic affairs, prediction of future reproduction costs is but another conjectural segment of a fanciful valuation procedure.

Some average of prices must be used in calculating reproduction costs if sudden fluctuations of prices are to be omitted. In several decisions an average of several years' prices has been employed to obtain such costs.[24] To illustrate further nonuniformity of valuation procedure, in 1934 one commission believed a five-year average of prices correct,[25] whereas another would not admit use of a five-year average during a depression.[26] Other commissions have chosen spot prices to calculate reproduction costs, notwithstanding Supreme Court opinion.[27]

II

A recent development in the valuation conflict is use of index numbers of construction costs and prices. Some commissions have examined these indices to determine the trend of prices,[28] a legal requisite of valuation which has previously been noted. The use of

[23] *Re Portland Elec. Pr. Co.* (Ore.), P. U. R., 1930D, 357; *Vincennes v. Vincennes Water Supply Co.* (Ind.), P. U. R., 1932A, 16; *Pub. Serv. Comm. of Missouri v. Missouri Utilities Co.*, P. U. R., 1932E, 449; *Re Southern Bell Telephone & Telegraph Co.* (S. Car.), P. U. R., 1933B, 181; *Montana Pub. Serv. Comm. v. Billings Gas Co.*, P. U. R., 1933D, 337; *Re Pacific Gas & Elec. Co.* (Cal.), 1 P. U. R. (N. S.), 1 (1933); *Re Ohio Bell Telephone Co.* (Ohio), 2 P. U. R. (N. S.), 113 (1934); *Illinois Commerce Comm. v. Pub. Serv. Co. of Nor. Ill.*, 4 P. U. R. (N. S.), 1 (1934); *Re Michigan Bell Telephone Co.* (Mich.), 10 P. U. R. (N. S.), 149 (1935).

[24] *Board of Pub. Util. Commissioners v. Elizabethtown Water Co.* (U. S. Cir. Ct.), P. U. R., 1930E, 373; *Elko-Lamoille Pr. Co. v. Pub. Serv. Comm. of Nevada*, P. U. R., 1933B, 191.

[25] *Illinois Commerce Comm. v. Pub. Serv. Co. of Nor. Ill.*, 4 P. U. R. (N. S.), 1 (1934).

[26] *Re Home Gas & Elec. Co.* (Colo.), 5 P. U. R. (N. S.), 107 (1934).

[27] *Re Alexandria Water Co.* (Va.), P. U. R., 1932C, 342; *Pub. Serv. Comm. of Missouri v. Missouri Utilities Co.*, P. U. R., 1932E, 449; *Re Lone Star Gas Co.* (Okla.), P. U. R., 1933C, 1; *Re Carolina Pr. & Lt. Co.* (S. Car.), 2 P. U. R. (N. S.), 259 (1934); *Dept. of Pub. Serv. v. Grays Harbor Ry. & Lt. Co.* (Wash.), 12 P. U. R. (N. S.), 178 (1936); *Pub. Serv. Comm. of Missouri v. St. Joseph Ry. Lt. Heat & Pr. Co.*, 14 P. U. R. (N. S.), 113 (1936).

[28] See n. 23.

index numbers or price series, which will be treated here, concerns measurement of cost of reproduction or even fair value. In endeavoring to make a practicable exit from this befuddling and ineffective segment of regulation procedure, the Maryland and Ohio commissions in particular have ventured the use of price indices in lieu of costly appraisals to determine fair value.[29] In a New York Public Service Commission opinion Dr. John Bauer's conversion of an earlier inventory of fixed assets of the New York Edison Company into a present fair value by means of the wholesale price index of the Bureau of Labor Statistics, excluding farm and food prices, was dismissed as "pure assumption."

Because the Ohio Commission's use of this method has not been contested in the courts and because the procedure was not the sole expressed means of measuring fair value,[30] attention will be devoted to the Maryland Commission's opinions,[31] one of which has been rejected by the Supreme Court. In the Chesapeake and Potomac Telephone Company case [32] the Maryland Commission assembled sixteen cost and price indices varying from the all-commodities price index of the Bureau of Labor Statistics to two special-purpose indices pertaining especially to telephone property. After weighting these indices "upon a principle not disclosed," as the Supreme Court said, a "trend of fair value" was determined, with an eight-year-old commission appraisal and district court opinion of fair value plus net additions serving as the valuation base. The range of present values obtained from multiplication of the 1923 valuation by these sixteen not closely related indices was from $24,983,000 to $36,056,000; not a notable difference if one recalls the disparity between company and commission appraisals of fair value or reproduction costs in other valuation cases.

The Supreme Court rejected this new valuation method for the following five reasons, taken in the order of the Court's presentation of them: (1) "An obvious objection is that the indices . . . were

[29] *Washington Heights Taxpayers Assoc. v. New York Edison Co.* (N. Y.), P. U. R., 1932E, 218.

[30] *Re Ohio Bell Telephone Co.* (Ohio), 2 P. U. R. (N. S.), 113 (1934). *Re Bluefield Telephone Co.* (W. Va.), P. U. R., 1926D, 209, and *Wheeling v. Natural Gas Co. of W. Va.* (W. Va.), 5 P. U. R. (N. S.), 471 (1934).

[31] *Re Chesapeake & Potomac Telephone Co.* (Md.), 1 P. U. R. (N. S.), 346 (1933); *Re Potomac Edison Co.* (Md.), P. U. R., 1933B, 6; *Re Conowingo Pr. Co.* (Md.), 10 P. U. R. (N. S.), 353 (1935).

[32] *West v. Chesapeake & Potomac Telephone Co.*, 295 U. S. 662 (1935).

intended merely to indicate price trends." (2) "Wide variation of results of the employment of different indices . . . impugns their accuracy as implements of appraisal." (3) "Sensible of this discrepancy, the Commission attempted a rule-of-thumb corrective . . . and thus rendered its process of valuation even more dubious and obscure." (4) Substitution "for such factors as historical cost and cost of reproduction [of] a 'translator' of dollar value . . . serves only to confuse the problem. . . ." (5) "A more fundamental defect in the Commission's method is that the result is affected by sudden shifts in price level," a conclusion of the Supreme Court considered previously in this paper.

The dissenters in this case, Justices Stone, Brandeis, and Cardozo, presented a detailed argument that, because the lower court and commission findings were rejected, and because the company, which had also presented a price index, had not offered evidence of confiscation, the Commission's order ought not be held confiscatory.[33] Mr. Justice Stone adds, further, "An examination of the present record will disclose that the results obtained by application of price indices to the historical cost of plant are far less variable than engineer's valuations and in general are probably more trustworthy. . . . Present fair value at best is but an estimate."

Perhaps the Maryland Commission was attempting to do more with these price indices than measure the change in the cost of reproduction. This Commission concluded that, if a return were permitted on a rate base of property purchased at high prices, "its owners would actually profit by the world-wide depression which has . . . brought distress to rate-payers." [34] It was further concluded that "fair value of a property . . . should be subject to the general changes in the value of the dollar." All this indicates that the Commission was using index numbers, not to measure cost of reproduction or fair value, but to determine the purchasing power of return on the rate base — a questionable, and certainly legally unsupportable, valuation procedure. If this was the desired goal, it

[33] The company and commission realized that the customary valuation procedure would require not less than two years and would cost the company alone at least $300,000. Consequently, the company and commission agreed to use index numbers in ascertainment of "present day costs." *Re Chesapeake & Potomac Telephone Co.* (Md.), 1 P. U. R. (N. S.), 346 (1933).

[34] *Re Chesapeake & Potomac Telephone Co.* (Md.), 1 P. U. R. (N. S.), 346 (1933).

could have been more readily achieved, and with more expectation of court approval, by paring down the rate of return.[35]

Although the Supreme Court was doubtless correct in its rejection of a valuation based on price indices which were not specifically applicable to the telephone company's property, a price index may be constructed or price series assembled by means of which reproduction costs may be determined without resorting to costly, time-consuming engineering appraisals. First, a detailed inventory of the property should be obtained. Thereafter, with a record of property additions and abandonments, prices may be applied to the inventory to obtain cost of reproduction. Each price series probably should be weighted in accordance with the proportion of cost of the property to which it applies to total property cost. Difficulties and probable errors would appear in obtaining (1) satisfactory price data for all types of assets, particularly for aged property, (2) accurate wage rates for each locality or region, and (3) proper allowance for changes in technological means of construction.

There would be further vitiation of effective regulation and closure of one possible exit to acceleration of the rate-fixing process if the Supreme Court has denied, or should in future cases deny, use of index numbers in measuring reproduction costs no matter what care might be given their study and construction. Even though the Court has not considered a case in which price series have been properly constructed and used, this excerpt indicates the possibility of a favorable future opinion:[36] "it is plain that such a use of relation of values [the company's price indices] of specific articles as of two given dates is quite distinct from the application of general commodity indices to a conglomerate of assets constituting a utility plant."

But price indices could not be the factual basis for final judgment on reproduction costs if sudden fluctuations of prices must be disregarded, though such use of prices would eliminate the need for engineering appraisals. Final legal judgment of this justifiable eco-

[35] *Dept. of Public Works of Washington v. West Coast Telephone Co.*, P. U. R., 1933A, 487; *Re Yonkers R. R. Co.* (N. Y.), P. U. R., 1933B, 61; *Kankakee Water Co. v. Gilbert* (U. S. Dist. Ct. — Ill.), P. U. R., 1933B, 145; *San Francisco v. Great Western Pr. Co.* (Cal.), P. U. R., 1933C, 487; *Re Utility Rates during Economic Emergency* (Pa.), 3 P. U. R. (N. S.), 123 (1934); *Re Ohio Bell Telephone Co.* (Ohio), 2 P. U. R. (N. S.), 113 (1934); *Illinois Commerce Comm. v. Pub. Serv. Co. of Nor. Ill.*, 4 P. U. R. (N. S.), 1 (1934); *Stuttgart v. Arkansas Pr. & Lt. Co.* (Ark.), 5 P. U. R. (N. S.), 161 (1934).

[36] *West v. Chesapeake & Potomac Telephone Co.*, 295 U. S. 662 (1935).

nomic procedure awaits further consideration of the problem by the Supreme Court.

III

Since 1930 the illusory public-utility valuation concept, going value, has been so much doubted or rejected by commissions and the Supreme Court that it may not long continue to confound regulators. Ever since utilities lost their plea for an allowance in the rate base for good will, the kindred concept, going value, has been presented by companies as an essential part of the rate base. Observers of this confusion of property value under regulation with property value of unregulated enterprises have deprecated going-value allowances,[37] although some students, notwithstanding Supreme Court opinions to the contrary,[38] have supported capitalization of development costs during the infancy of a business, provided these costs have not yet been paid by consumers.[39]

Until recently state commissions have not troubled themselves with failure of the Supreme Court to reconcile the McCardle case [40] with the Galveston and Des Moines decisions; [41] in the Galveston and Des Moines cases omission of going-value allowances was not held to be confiscatory. Instead, many of them implicitly adhered to the procedure believed to be most nearly in accord with Supreme Court opinion, "the duty of finding the going concern value." [42] Consequently, between 1929 and 1934 commissions commonly determined the allowance for going value in a conjectural or an unexplained manner.[43] Or, as the Connecticut Public Utilities Commission

[37] Two articles of one observer may be cited: Lewis, B. W., "Going Value — Comments on Its Nature and Legal Status," *American Economic Review*, 17 (1927) : 657; *idem*, "Why 'Going Value' Should be Discarded in Rate Making," *Public Utilities Fortnightly*, 8 (1931) : 588.

[38] *Galveston Elec. Co. v. Galveston*, 258 U. S. 388 (1921), *et seq.*

[39] Sumner, John, "Going Value: Its Validity and Logical Application," *Journal of Land and Public Utility Economics*, 4 (1928) : 113.

[40] *McCardle v. Indianapolis Water Co.*, 272 U. S. 400 (1926).

[41] *Galveston Elec. Co. v. Galveston*, 258 U. S. 388 (1921); *Des Moines Gas Co. v. Des Moines*, 238 U. S. 153 (1914).

[42] *Pub. Serv. Comm. of Missouri v. East Missouri Pr. Co.*, P. U. R., 1933E, 388.

[43] *Re Milwaukee Elec. Ry. & Lt. Co.* (Wis.), P. U. R., 1930C, 426; *Re Oklahoma Natural Gas Corp.* (Okla.), P. U. R., 1931B, 470; *Denver Union Stock Yard Co. v. U. S.* (U. S. Dist. Ct.), P. U. R., 1932C, 225; *Re Alexandria Water Co.* (Va.), P. U. R. 1932C, 342; *Scranton-Spring Brook Water Serv. Co. v. Pub. Serv. Comm. of Pa.*, P. U. R., 1932C, 471; *Pub. Serv. Comm. of Missouri v. Missouri*

stated, "going concern value . . . must necessarily be speculative and arbitrary, yet in view of the court decisions a moderate amount will be allowed." [44]

Between 1929 and 1934, however, a few commissions rejected company requests for going-value allowances, although in earlier cases some of these commissions had granted rate-base sums for going value. The Montana Public Service Commission did not make such an allowance because the property had been valued on reproduction costs; [45] in Oklahoma the company's estimate of going-concern value was labeled "purely fictional"; [46] and the California Railroad Commission did not believe going value to be consonant with the use of historical cost as the rate base.[47] There were other reasons for denying such allowances, principally the payment of the costs incident to going value by customers or ample allowance for this intangible among overhead expenses.[48]

In none of the recent cases has the Supreme Court flatly pronounced going value an unjustified part of a rate base, but it has questioned this long common valuation allowance more critically than previously it was wont to do. In fact, for various reasons it has rejected requests for going value in three significant depression-time rate cases. Perhaps this less phlegmatic attitude toward going value foretells a gradual about-face on this valuation element.

In the Los Angeles Gas and Electric Corporation opinion of 1933 the Court in one sense supported the California Commission's refusal to allow a request for a $9,000,000 going-concern value, because it believed the generosity of the Commission on other valuation items gave the company something that might be called going value.[49]

Utilities Co., P. U. R., 1932E, 449; *Re Potomac Edison Co.* (Md.), P. U. R., 1933B, 6; *Re Home Gas & Elec. Co.* (Colo.), 5 P. U. R. (N. S.), 107 (1934).

[44] *Rabbett v. Northern Connecticut Pr. Co.* (Conn.), P. U. R., 1933D, 119.

[45] *Re Bowdoin Utilities Co.* (Mont.), P. U. R., 1931B, 20.

[46] *Re Lone Star Gas Co.* (Okla.), P. U. R., 1933C, 1.

[47] *Re Pacific Gas & Elec. Co.* (Cal.), 1 P. U. R. (N. S.), 1 (1933).

[48] *Elko v. Elko-Lamoille Pr. Co.* (Nev.), P. U. R., 1931C, 14; *Re Niagara Hudson Pr. Corp.* (N. Y.), P. U. R., 1932C, 486; *California Farm Bureau Fed. v. San Joaquin Lt. & Pr. Co.* (Cal.), P. U. R., 1932D, 310; *Re Central Hudson Gas & Elec. Corp.* (N. Y.), P. U. R., 1932E, 497; *Montana Pub. Serv. Comm. v. Billings Gas Co.*, P. U. R., 1933D, 337; *Re Ohio Bell Telephone Co.* (Ohio), 2 P. U. R. (N. S.), 113 (1934).

[49] *Los Angeles Gas & Elec. Corp. v. R. R. Comm. of California*, 289 U. S. 287 (1933). This "offset" of values, which may be termed the Court's going-value allowance, amounted to approximately $5,500,000.

The Court further observed that "an examination of the evidence offered by the company upon this subject shows it to be of a highly speculative and uncertain character." [50]

A year later in two cases, both of which originated in Ohio, the Supreme Court appears to have doubted the propriety of allowances for going value even more than it had done in the Los Angeles Gas and Electric Corporation case. After noting that "going value . . . upon proof of its existence . . . may have a place in the base upon which rates are to be computed," the Court in the Dayton Power and Light Company case rejected going-value evidence and requests in these terms: [51] "Going value is not something to be read into every balance sheet as a perfunctory addition. . . . We cannot in fairness say that after valuing the assets upon the basis of a plant in successful operation, there was left an element of going value to be added to the total."

Similarly, after the Ohio Public Utilities Commission had concluded that the "burden of building up patronage may be negligible where there is little competition" and that going-value estimates were "so vague as to be little more than guesses," [52] the Supreme Court in the Columbus Gas and Fuel Company case thus limits the going-value allowance: [53]

> The record justifies a holding that it was reflected . . . particularly in the appraisal of the physical assets as part of an assembled whole. . . .
>
> The going value of the Ohio Fuel Gas Company was placed . . . so high ($12,000,000) as to be excessive almost on its face, and the impression of exaggeration is confirmed when the appraisal as a whole is resolved into its elements.

Never before has the Supreme Court been so critical of going value. Whether its rejections or trenchant comments on going value point toward either future omission or reduction of going-concern allowances in a legally acceptable rate base cannot be positively

[50] The four "conjectural" methods for going-value measurement and the resulting sums presented by company witnesses were: (1) one year of gross income, $15,801,208; (2) 15 per cent of reproduction cost less depreciation, $10,638,000; (3) $25 per customer meter, $8,886,700; and (4) the difference between 8 per cent return on construction cost and estimated net earnings for the second to seventh years inclusive of the company's life, $8,721,878.

[51] *Dayton Pr. & Lt. Co. v. Pub. Util. Comm. of Ohio*, 292 U. S. 290 (1934).

[52] *Re Columbus Gas & Fuel Co.* (Ohio), P. U. R., 1933A, 337.

[53] *Columbus Gas & Fuel Co. v. Pub. Util. Comm. of Ohio*, 292 U. S. 398 (1934).

answered until it gives additional opinions. State commissions, meanwhile, by virtue of these decisions, have generally been refusing to permit going-value allowances.[54]

IV

There has been no alteration of Supreme Court views concerning fair value during these depression years, even though in hybrid-fair-value estimates cost of reproduction has frequently fallen below prudent investment. Although the fact may not influence court opinion, catastrophic price changes during the last six years should have awakened jurists, the regulated, and the regulators from apathetic thinking that reproduction costs will never decline or will forever increase. This myth of increasing prices was apparently firmly intrenched in legal reasoning on utility valuation during the high-price period of the World War era and the succeeding price conditions of the 'twenties. Furthermore, it is an anomaly that plant reproduction, particularly reproduction of an identical plant, is assumed to exist, and prices thus averaged or forecast; whereas no one offers evidence of the actual date or dates of property replacement. Of what use, therefore, is a reproduction appraisal of a plant in 1932 if the contents of the plant will be replaced at unpredictable times and at unpredictable prices? Unless permanent hyperinflation of prices may be foreseen, it seems infinitely better that any modest excess of plant-replacement cost over historical cost be met with further borrowing or a more than ample rate of return.

Not only have dissenting valuation opinions of the Supreme Court been disregarded in economic environment suitable to recantation, but also the majority of this Court have added further ambiguities to the process. In addition to the opinion that price trends be considered in fixation of a regulated company's rate base, a requirement that supposes superhuman ability to forecast prices and which has

[54] *Memphis v. Southern Bell Telephone Co.* (Tenn.), 6 P. U. R. (N. S.), 464 (1934); *Re Yonkers R. R. Co.* (N. Y.), 9 P. U. R. (N. S.), 337 (1935); *Re Upstate Telephone Corp. of N. Y.* (N. Y.), 13 P. U. R. (N. S.), 134 (1936); *Dept. of Pub. Serv. of Washington v. Pacific Pr. & Lt. Co.*, 13 P. U. R. (N. S.), 187 (1936); *Herr v. Lancaster Suburban Water Co.* (Pa.), 14 P. U. R. (N. S.), 369 (1936); *Cheltenham & Abington Sewerage Co. v. Pub. Serv. Comm.* (Pa. Sup. Ct.), 15 P. U. R. (N. S.), 99 (1936); *Blytheville v. Blytheville Water Co.* (Ark.), 15 P. U. R. (N. S.), 177 (1936); *Southern Bell Telephone Co.* (Okla.), 16 P. U. R. (N. S.), 1 (1936).

bewildered commissions in their selection of prices to measure reproduction costs, the majority of the Court awaited a decline in construction costs to order omission of sudden fluctuations of prices in determination of fair value. This recently announced requisite is attuned to other legal valuation dicta in that no attempt was made to define or to limit the meaning of sudden fluctuations of prices.

The snail pace of public-utility regulatory procedures, not to mention frequent court appeals and retrials, has limited effectiveness of utility rate and service controls. A commission which has thoroughly investigated a public-utility system and faced a reasonable amount of court inquiry is fortunate to be done with a rate case in one or two years. Commission-enforced rate reductions, therefore, were too much to expect commonly during this depression when commission staffs and appropriations had been reduced. Possibly effectiveness of regulation — ineffectiveness of regulation is partly traceable to the legal valuation process — could be enhanced if reproduction cost appraisals could be replaced by proper use of price series and a continuous property inventory. Certainly in the Chesapeake and Potomac case the Court did not indicate a willingness to approve this short cut. It is unfortunate, moreover, that the Supreme Court has never considered effective regulation one of the goals toward which their decisions should be directed. Indeed, the Court has generally seemed oblivious of this end. Mr. Justice Brandeis, however, observes that [55] ". . . regulation cannot be effective unless the legality of the rates prescribed may, if contested, be determined with reasonable promptness. . . . I cannot believe that the Constitution, which confers upon Congress the power of rate-regulation, denies to it power to adopt measures indispensable to its effective exercise."

Only going-value allowances have been questioned by the Supreme Court during the last six years. Further opinions dealing with this questionable valuation allowance may unmistakably reject going value as part of fair value in view of the rebuffs given in recent cases. Thus this recent dubiousness on going value is some consolation to public-utility regulators and consumers, who must accede to other equally uncertain, but legally acceptable, valuation technique.

Commissions will continue to grope for workable valuation rules, to guess the prices to be used in measuring cost of reproduction, or

[55] *St. Joseph Stock Yards Co. v. U. S.*, 298 U. S. 38 (1936).

to approximate the proportions to be allowed the diverse valuation elements in the fair-value synthesis. Ineffectiveness of regulation, meanwhile, will continue, appropriated funds for commission regulation will always be insufficient because of the costly valuation procedure, customers cannot be assured justifiable rate reductions, and regulation chaos will encourage further support of governmental ownership of utility plants. To repeat Mr. Justice Stone's statement concerning public-utility valuation, "courts have been projected into the most speculative undertaking imposed upon them in the entire history of English jurisprudence."

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SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. IX

DOW V. BAXTER

PAPERS IV–VIII (1–5) in this series show clearly that rather large differences in growth rates and other features among mycelia even of the same species of certain wood-destroying fungi may exist. The rate of growth of *Poria ferrea* on *Alnus rubra* from Oregon, for example, was 24.2 mm. in two weeks, whereas an isolate of the same species on Salix from Oregon grew only 16.8 mm. in the same period. However, in spite of such differences it is held that when a large number of cultures of many species are compared, broad lines of distinction between certain species and groups of other species can be observed. The growth characteristics of these fungi in culture are, therefore, to be used to supplement their morphological features.

Between 1,200 and 1,500 cultures are now transferred yearly in this study of the growth habits of the resupinate polypores. Further isolations from different substrata, from new species found, or from plants which have already been described but which are obtained from other regions, are being added to this collection constantly and constitute a part of a program of research which deals with the resupinate polypores of North America. Descriptions of twelve porias are presented in this paper.[1] Among them are four new species and several forms which are rare to North America. In addition, the characteristics of ten resupinate polypores in culture are discussed. The growth features of these polypores are presented in Table I (pp. 288–289). The fungi are grouped in the following categories:[2]

[1] Throughout the work on these monographs I am indebted to many institutions and individuals for help. My appreciation is expressed to Professors T. G. Halle and Gunnar Samuelson, of the Naturhistoriska Riksmuséet in Stockholm, with whom I have had the pleasure of association. Thanks are also due the authorities at the New York Botanical Garden.

[2] The terms used in this classification are defined in Papers V, VI, and VIII (2, 3, 5) of the series.

A. RATE OF GROWTH

Rapid growth

Poria subacida on Tsuga heterophylla from Washington

Poria albipellucida on Tsuga heterophylla from Washington

Poria nigra on Quercus velutina from Illinois

Poria eupora on Quercus borealis maxima from Michigan

Polyporus alboluteus on Picea glauca from Alaska

Fomitiporia dryophila Isolate II on Carpinus sp. from Louisiana

Slow growth

Trametes heteromorpha on Picea sitchensis from Alaska

Fomes Everhartii on Quercus borealis maxima from Michigan

Poria luteofibrata on Pinus rigida serotina from Florida

Poria crustulina on Picea glauca from Alaska

B. RANGE OF TEMPERATURE FOR GROWTH

Large range

Poria albipellucida on Tsuga heterophylla from Washington

Fomitiporia dryophila Isolate II on Carpinus sp. from Louisiana

Small range

Poria subacida on Tsuga heterophylla from Washington

Polyporus alboluteus on Picea glauca from Alaska

Poria nigra on Quercus velutina from Illinois

Poria crustulina on Picea glauca from Alaska

Trametes heteromorpha on Picea sitchensis from Alaska

Fomes Everhartii on Quercus borealis maxima from Michigan

Poria luteofibrata on Pinus rigida serotina from Florida

Poria eupora on Quercus borealis maxima from Michigan

C. TEMPERATURE FOR BEST GROWTH

High temperature

Fomes Everhartii on Quercus borealis maxima from Michigan

Poria nigra on Quercus velutina from Illinois

Fomitiporia dryophila Isolate II on Carpinus sp. from Louisiana

Average temperature

Polyporus alboluteus on Picea canadensis from Alaska

Poria albipellucida on Tsuga heterophylla from Washington

Trametes heteromorpha on Picea sitchensis from Alaska

Poria eupora on Quercus borealis maxima from Michigan

Poria luteofibrata on Pinus rigida serotina from Florida

Poria crustulina on Picea canadensis from Alaska

Poria subacida on Tsuga heterophylla from Washington

D. EFFECT OF LIGHT

Best growth in dark

Poria albipellucida on Tsuga heterophylla from Washington

Fomes Everhartii on Quercus borealis maxima from Michigan

Poria eupora on Quercus borealis maxima from Michigan

Fomitiporia dryophila Isolate II on Carpinus sp. from Louisiana

Equal growth in light and dark

Trametes heteromorpha on Picea sitchensis from Alaska

Poria subacida on Tsuga heterophylla from Washington

Poria luteofibrata on Pinus rigida serotina from Florida

Polyporus alboluteus on Picea glauca from Alaska

Poria nigra on Quercus velutina from Illinois

Poria luteofibrata, sp. nov.

(Plates I–III)

Type specimen:

Poria luteofibrata, sp. nov., on *Pinus rigida serotina*, Olustee Experimental Forest, Olustee, Florida.

Fructificatio annua, effusa usque ad 1 metrum vel minus, ex substrato inseparabilis, ad 7 mm. crassa; conspicue rhizomorpha infra corticem vel in substrati ligno; sterilis, interdum aetate fertilis, albus vel albido-fulvus; subiculum plerumque minus quam 0.5 mm., margine concolor; tubi 0.5 ad 6 mm. plerumque 5–6 mm. longi, haud stratosi; aperturae valde luteae, demum pallide aurantiaco-luteae, vel pallide ochraceae, angulosae, fimbriatae, 0.5–3 plerumque 0.5–1 mm. diam.; basidia 2- vel 4-spora;

TABLE I

Growth Characteristics of Resupinate Polypores on Malt Agar *

Name	In Light						In Dark					
	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Character of margin	Agar discoloration	Pore formation	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Character of margin	Agar discoloration	Pore formation
Polyporus albolutens on *Picea canadensis* from Alaska	41.0	White to "light cinnamon-drab"	Cottony, radiating	No border, radiating fans	None	None	41.0	White to "light cinnamon-drab"	Cottony, radiating	No border or indefinite	None	None
Poria eupora on *Quercus borealis maxima* from Michigan	32.0	White to "Tilleul buff"	Arachnoid to flaky	No border	None	None	41.0	White	Flaky, radiating	No border	None	None
Fomes Everhartii on *Quercus borealis maxima* from Michigan	7.4	Cream-buff to "honey yellow"	Silky	Definite to indefinite	Present	None	15.6	White to "Antimony yellow" to dark olive-buff	Silky to cottony	Definite	Present	None
Poria albipellucida on *Tsuga heterophylla* from Washington	41.0	White	Flaky	Indefinite	None	None	41.0	White	Flaky	Indefinite	None	None
Poria luteofibrata on *Pinus rigida serotina* from Florida	17.4	White to "Naples yellow" to "mustard yellow"	Silky, concentric-ring growth	Indefinite	None	None	25.4	"Naples yellow" to "primuline yellow"	Silky, concentric-ring growth	No border or indefinite	None	None

Poria nigra on *Quercus velutina* from Illinois	18.6	White to "pinkish buff" to "avellaneous" to "wood brown"	Cottony	No border	None	None	27.8	White	Cottony	No border	None	None
Poria subacida on *Tsuga heterophylla* from Washington	41.0	White	Cottony	Slightly concentric	None	None	41.0	White	Cottony	No border	None	None
Trametes heteromorpha on *Picea sitchensis* from Alaska	6.25	White to "Verona brown"	Silky	Definite	None	None	18.0	White	Silky to cottony	Indefinite	None	None
Fomitiporia dryophila Isolate II on *Carpinus sp.* from Louisiana	25.1	"Maize yellow" to "isabella color" to "buckthorn brown"	Chamois	Indefinite to definite	None beyond culture	None	41.0	White to "cinnamon-buff" to "buckthorn brown"	Cottony	Indefinite to definite	None	None
Poria sitchensis on Tsuga heterophylla from Wrangell, Alaska	41.0	White to "cartridge buff"	Chamois to cottony	No border, slightly radiating fans	None	None	41.0	White	Cottony to chamois, slightly flaky	No border, slightly radiating fans	None	None

* The terms used in this table are defined in Paper VIII of this series.

sporae uniguttulatae, late ellipticae vel oblongo-ellipticae, 4–6.5 (5.5–6.5 × 3–4) 2–4 μ; hyphae hyalinae, flexuosae, distanter septatae, 1–4 μ latae, connectiones constrictae praesentes sed non frequentes. Specimen typicum in Herb. Dow V. Baxter conservatum: Legit prope Olustee, Florida, Feb., 1935, Dow V. Baxter n. ZZ–23155.

Fructification annual, effused for 1 meter or less, inseparable, up to 7 mm. thick; conspicuously rhizomorphic — at least underneath the bark or on the wood of the substratum; margin subiculose, tomentose, sterile, sometimes becoming fertile with age, white to "warm buff"; subiculum mostly less than 0.5 mm. thick, concolorous with margin; tubes 0.5–6 mm., mostly 5 6 mm. long, not stratified; mouths "deep chrome" drying to "pale orange-yellow" to "clay color," angular, fringed, 0.5–3, mostly 1–2 to a mm.; basidia 2–4-spored; spores uniguttulate, broadly ellipsoid or oblong-ellipsoidal, 4 6.5 (5.5 6.5 × 3 4) 2 4 μ; hyphae hyaline, flexuous, occasionally septate, 1 4 μ wide, clamp connections present but not frequent.

Allied species. — This plant in a fresh, growing state is easily distinguished because it is bright yellow, possesses large tubes, and is somewhat rhizomorphic. The color and habit of growth of *Poria albolutescens*, also found on coniferous wood (mostly of western and north-central distribution), show some resemblance to those of this new species. *P. albolutescens* is more felty in texture than is the plant described here. The newly discovered species from Florida is related also to a plant called *Pol. flavovirens* in Romell's herbarium at the Riksmuséet in Stockholm, but they may be readily distinguished by the fact that the tube length is much greater in the American species. In dried collections the southern plant fades so as to suggest the color of *P. subacida.* The large tubes, together with the crisp nature of herbarium specimens of *P. luteofibrata*, are a further similarity to *P. subacida.* The yellow rhizomorphs found underneath the bark or on the wood infected with the southern poria are distinctive.

Cultures. — Isolated from *Pinus rigida serotina*, Olustee, Florida. The chief features of this yellow fungus in culture are presented in Table I. *P. luteofibrata* can be readily distinguished by its soft, light, and fluffy growth of cottony mycelium. This extends out from wood blocks (white pine and red gum, also) 2.5 to 3 cm.,

and in nine-month-old cultures becomes arachnoid and reaches in long, thin strands and fibrous sheets from one block to another. This coniferous fungus grows equally well on white pine and red gum blocks, with no pore formation. No other resupinate thus far cultured exhibits this character. *P. floridana* forms a dense thick mat of mycelium on wood blocks, but this species is not yellow and the mat is not so fluffy as the down of the cormorant. *P. luteofibrata* exhibits rhizomorphic tendencies of growth in culture, a characteristic which is not present in *P. floridana*.

Habitat. — *Pinus rigida serotina.*

Distribution. — Florida.

Poria albipellucida, sp. nov.

(Plate IV)

Type and important specimen:

Poria albipellucida, sp. nov., on *Thuja plicata*, Vancouver, British Columbia. Type. Coll. Dow V. Baxter, Aug. 23, 1935. Herb. Dow V. Baxter.

Poria albipellucida, sp. nov., on *Tsuga heterophylla*, Olympic Hot Springs, Olympic National Forest, Washington. Coll. Dow V. Baxter, Sept. 12, 1936. Herb. Dow V. Baxter.

Fructificatio annua, tenuis, alba vel pellucida, primum orbicularis 0.5 × 0.5 cm. mox cum aliis confluens et aream irregularem corticis 3.5 × 15 cm. tectans, margine 3.5 × 15 cm. ex cortice separante; demum omnino separabilis; margo niveo-albus, 0.3 mm. latus aetate interdum fertilis; subiculum conspicuum, minus quam 0.3 mm. latum, demum corneum, pellucidum in exemplis siccatis; tubi 0.5–2 mm. longi; aperturae plerumque angulares, 2–4, plerumque 3–4 in uno mm., albae permanenter, etiam in speciminibus exsiccatis, sed interdum siccitate ochraceo-cinnamomeae, basidia 8–13 × 5.5–7 μ; sporae hyalinae, reniformes vel cylindricae, 4 × 1–2 μ, paxilli hyphales incrustati, 11–22 × 4 μ; hyphae hyalinae, saepe incrustatae, raro septatae, 2–3 μ in diam.; anastomoses adsunt. Specimen typicum in Herb. Dow V. Baxter conservatum: Legit prope Vancouver, British Columbia, Aug., 1935, Dow V. Baxter n. WW–23155a.

Fructification annual, thin, white or translucent, at first occurring in more or less orbicular patches 0.5 cm. in diameter which enlarge and coalesce so as to cover an irregular area of the bark as much as 3.5 × 15 cm. in extent, separating at the margins from the

substratum; entire plant separable; margin snow-white at first, less than 0.3 mm. wide, then disappearing or becoming fertile; subiculum conspicuous, less than 0.3 mm. wide, becoming somewhat horny and translucent in appearance in dried specimens; tubes 0.5–2 mm. in length, mouths mostly angular, 2–4, mostly 3–4 to a mm., white and usually remaining so in herbarium specimens but sometimes upon drying or bruising turning "cinnamon-buff"; basidia 8–13 × 5.5–7 μ; spores hyaline, allantoid or cylindrical, 4 × 1–2 μ; hyphal pegs encrusted, 11–22 × 4 μ; hyphae hyaline, often encrusted, rarely septate, 2-3 μ in diameter, clamp connections present.

Allied species. — This distinctive plant is readily recognized by: (*a*) its habit of growth, (*b*) its thin nature, (*c*) the water-soaked appearance of the tubes when bruised, (*d*) the separation from the substratum at the margins upon drying, (*e*) the fact that the dried plants are not soft but horny.

Many of the white porias are soft in texture, and so are readily dissociated from the plant described here. The habit of growth alone should distinguish it from the other known resupinate polypores. Collections of this species have been called *P. expalescens* Karst. The latter plant, according to Romell (9), is a resupinate form of *P. dichrous* Fr. The tubes of *P. dichrous* are waxy, less than 1 mm. long, and separable from the context. These features, together with differences in color, will readily distinguish the two plants from each other.

Cultures. — Isolated from *Tsuga heterophylla*, Olympic Hot Springs, Olympic National Forest, Washington. The abundance of submerged hyphae and the fact that the plant grows equally well in the light and the dark are the chief characteristics of this fungus.

This coniferous fungus grows equally well on white pine and red gum blocks. A thin sheet of arachnoid to very slightly rhizomorphic mycelium is formed over the wood in fanlike growth. In six-month-old cultures the mycelium is white to buff-colored, with no pore formation.

Habitat. — *Thuja plicata, Tsuga heterophylla.*

Distribution. — British Columbia, New Mexico, Washington.

Remarks. — The encrustations at the ends of the hyphae are more numerous in specimens found in less humid environments than in those of coastal British Columbia and Washington.

Poria sitchensis, sp. nov.

(Plates V; VI, Fig. 2; VII, Fig. 1)

Type and important specimens:

Poria sitchensis, sp. nov., on *Picea sitchensis*, Sitka, Alaska. Type. Coll. Dow V. Baxter, Sept. 1, 1933. Herb. Dow V. Baxter.

Poria sitchensis, sp. nov., on *Tsuga heterophylla*, Sitka, Alaska. Coll. Dow V. Baxter, Sept. 1, 1933. Herb. Dow V. Baxter.

Poria sitchensis, sp. nov., on *Picea sitchensis*, Tenakee, Alaska. Coll. Dow V. Baxter, Aug. 29, 1933. Herb. Dow V. Baxter.

Poria sitchensis, sp. nov., on *Picea sitchensis*, Requa, California. Coll. Dow V. Baxter, June 26, 1933. Herb. Dow V. Baxter.

Fructificatio perennis, late effusa aliquando ad $\frac{1}{2}$ metrum, raro 8 mm., plerumque 2–3 mm. crassa; strata vetustiora cretacea; margines primo tomentosi, mox fertiles et in exemplis veteribus saepe aspectu resinosi, primo albidi vel pallide rufidulo-ochracei, demum parte exteriore argillaceo-ochracei vel brunnei vel fusci; tubi 0.5–3 mm. plerumque 2 mm. longi, saepe dispositi in 2 vel 3 stratis vel raro 7-stratosi; aperturae albae vel pallide rufo-ochraceae siccitate ochraceo-cinnamomeae, 4–5 plerumque 4 in uno mm., suborbiculares; saeptis crassis; basidia 9–11 × 1 2 μ; sporae cylindricae vel allantoideae, hyalinae, 3.5–4.5 (4 × 1–1.5) 1–2 μ; cystidia nulla; paxilli hyphales saepe subcylindrici prominentes 15–18 μ in lumen tuborum; hyphae hyalinae, 2–3 μ diam., muri tenues, anastomoses nullae. Specimen typicum in Herb. Dow V. Baxter conservatum: Legit prope Sitka, Alaska, Sept., 1933, Dow V. Baxter n. XX–23155a.

Fructification perennial, broadly effused sometimes for a distance of 0.5 of a meter, up to 8 mm., mostly 2–3 mm. thick, old layers becoming chalky; margins at first tomentose, soon becoming fertile and in old specimens often turning resinous in appearance, at first whitish or "pale pinkish buff," the border portions later becoming "clay color" to "Rood's brown" to blackish; tubes 0.5–3 mm., mostly 2 mm. long, often stratified in 2 or 3 and up to 7 layers; mouths white to "pinkish buff," sometimes drying to "cinnamon-buff," 4–5, mostly 4 to a mm., subround; dissepiments thick; basidia 9–11 × 1–2 μ; spores cylindrical or allantoid, hyaline, 3.5–4.5 (4 × 1–1.5) 1–2 μ; no cystidia, but subcylindrical hyphal pegs often present and projecting as much as 15–18 μ into the lumen of the tubes; hyphae hyaline, 2–3 μ in diameter, thin-walled, no clamp connections.

Allied species. — Attempts were made to locate this polypore in various European herbaria, but it was soon apparent that the poria must be new and North American. It is allied to *P. attenuata subincarnata* Pk. (*P. subincarnata*). *P. subincarnata* is, however, a thin plant. The new species differs further from that plant in exhibiting a resinous border or showing shades of red in the marginal portions, and it does not display the cracking so characteristic of *P. subincarnata*. *P. montana*, also, is related to the plant described here. The elongate-ellipsoid spores of *P. montana* are 5–7 × 2–3 μ (Shope), whereas those of *P. sitchensis* are somewhat smaller, i.e. mostly 4 × 1–1.5 μ. This difference is a relatively small one, but, in addition, the margins of *P. montana* do not exhibit the resinous features of the margins of the plant described here, and the mouths are larger and in dried specimens have a tendency to glisten. *P. sitchensis* has a smooth surface, and the mouths do not glisten. This last distinction, however, is not a significant one.

P. sitchensis also suggests, macroscopically, a small-pored growth form of *T. serialis*. The spores of the latter plant, however, are much larger, i.e. 7–9 × 2–3 μ.

Cultures. — Isolated from *Picea sitchensis*, Sitka, Alaska. The features of old cultures of this fungus suggest those of the margins in the fruiting body. The fungus is white at first (like that of *Trametes serialis*) but later exhibits brown or red-brown areas. A resinous-like liquid is secreted from the mycelium. This dries and gives to parts of the culture a resinous and brown color which suggests the features that characterize the borders of the fruiting body as found in nature. The brown mycelium occurs in lumps and finally covers a large area of the culture. This characteristic may be used to separate the fungus from *T. serialis* if difficulty is experienced in distinguishing between the two fruiting bodies.

Habitat. — *Picea sitchensis*, *Pinus monticola*, *P. ponderosa*, *Tsuga heterophylla*.

Distribution. — Alaska, California, Idaho, New Mexico.

Decay. — The badly decayed wood does not itself change color appreciably, but beneath the fruiting structure it often appears as a chalky mass, largely because of the abundance of white mycelium. This "chalk" can be rubbed from the decayed wood onto

the fingers as readily as that of the fruiting body of *Fomes laricis*. The mycelium may also form small sheets in the badly decayed portions of the punky wood.

Polyporus alboluteus Ellis & Ev., Bull. Torr. Bot. Club, 25 : 513. 1898

Fomes alboluteus Ellis & Ev., Proc. Acad. Phila., 1895 : 413.
Aurantiporellus alboluteus (Ellis & Ev.) Murr., Bull. Torr. Bot. Club, 32 : 486. 1905.
Irpex Woronowii Bres., Ann. Myc., 18 : 42. 1920.

Important specimen:
Irpex Woronowii Bres., sp. nov., Herb. of Bresadola, Stockholm.

Fructification annual, spongy, soft, effused in a resupinate condition for 1 meter or more or extending in elongated patches in the checks of decorticated wood for almost the entire length of the log, but usually only about 50 cm. long, occasionally narrowly reflexed, reflexed portion 0.5–3.5 cm. wide, separable from the substrata in corky sheets; surface of reflexed portion pubescent, azonate, whitish at first, soon "xanthine orange," "apricot orange" to "hazel," when dried sometimes turning very dark, i.e. "light seal brown," or "bone brown" bleaching to whitish; context spongy, "zinc orange" or "xanthine orange," 0.2–3 cm. thick; hyphae of the context both hyaline and brown, 4–8 μ in diameter, occasionally branched, often collapsed in herbarium material, walls 1 μ thick, spaces between the hyphae often 9–26 μ or more wide, tubes 1–3 cm. long, concolorous with context or drying to "Hay's russet" or "carob brown" and becoming brittle; mouths "xanthine orange" to "Hay's russet," "carob brown" or becoming blackish in herbarium specimens or sometimes fading to "cartridge buff," 1–4 mm., usually 1.5 mm. broad, angular, lacerate, frequently splitting and becoming toothlike; basidia 2.5–3 $\times$ 4.5 μ; spores elongate-ellipsoid, often apiculate, smooth, hyaline, 7–9 $\times$ 2–3 μ; cystidia abundant, hyaline, cylindric, 7–10.5 μ in diameter, often collapsed, projecting as much as 40–60 μ.

Allied species. — *Polyporus alboluteus* and *P. fibrillosus*, both of which occur rather frequently on spruce, particularly in the northwest, are closely allied. The colors of the two plants are often similar. The mouths of *Polyporus alboluteus* are very large, 1–4 mm. broad, whereas those of *P. fibrillosus* are 1–2 to a mm. The tubes of the former plant are 1–3 cm. long, but those of *P. fibrillosus* are

only 2–5 mm. in length. The context of both species becomes bright orange red or red when touched with KOH solution.

Habitat. — *Abies grandis, Picea canadensis, P. engelmannii, P. sitchensis, Populus trichocarpa.*

Distribution. — Alaska, Arizona, Colorado, Idaho, Michigan, New York, Utah, Washington, Wyoming.

Occurrence. — This fungus occurs on decorticated logs of windthrown timber in the montane and subalpine zones of the central Rocky Mountains. In the Rockies it is also found on old timbers in mines. In the northern sections of the coast forests the fungus commonly grows at lower altitudes. In the Chugach National Forest in Alaska it is found abundantly on Sitka spruce.

Remarks. — I cannot see any such resemblance as that stated by Bresadola, and recorded by Bourdot and Galzin, also, of the plant *Irpex Woronowii* Bres., sp. nov., in the Bresadola Herbarium at Stockholm to a resupinate *Trametes odorata* or *Lenzites saepiaria*. The spores of the plant at Stockholm are given as "7–9 × 3–4 μ."

Poria taxicola (Pers.) Bres., Atti Accad. Rovereto III, 3 : 80. 1897

Important specimens:

Polyporus haematodes Rostk. in Sturm, Deutschl. Fl. Pilze, 17 : 127. 1838.
Polyporus incarnatus Karst. ex Romell, Hymen. Lapland, Arkiv für Botanik, 11 : 30. 1911.
Polyporus rufus (Schrad.) Fr., Syst. Myc., 1 : 379. 1821 (?).
Merulius Ravenelii Berk., Grevillea, 1 : 69. 1872 (?).
Polyporus haematodus Rostk., L. Romell. Herb. Bresadola, Stockholm.
Poria taxicola (Pers.) Bres., Torrend, 1904. Herb. Bresadola, Stockholm.
Poria taxicola (Pers.) Bres., Abbé Bourdot, France. Herb. Bresadola, Stockholm.

Fructification annual, somewhat merulioid and gelatinous when fresh, effused in patches usually up to about 15 cm. long, on bark or decorticated wood, separable when fresh, 1–1.5 mm. thick; margin white to "cartridge buff" and remaining light-colored in herbarium specimens, pubescent, averaging 1–2 mm. wide; subiculum conspicuous, white to "cartridge buff," up to 1 mm., but mostly less than 0.5 mm. thick; tubes in one layer, often oblique, up to 1 mm., mostly less than 0.5 mm. long, "vinaceous-brown," "diamine brown," to "bone brown" to "blackish brown"; mouths concolorous with the tubes, circular, 3–4, mostly 3 to a mm., rather thick-walled; dissepiments remaining entire,

smooth; basidia 4-spored, 10–14 × 3–4 μ; spores cylindrical, curved, 4 × 1–1.5 μ; hyphae of the subiculum hyaline, thick-walled, much branched and loosely interwoven, septate, 4–6 μ in diameter, frequently swollen; hyphae of the hymenium brown, 3–4 μ in diameter, encrusted.

Allied species. — Burt (6) calls attention to the fact that the genus Merulius is closely connected on one side with certain species of the Thelephoraceae and on the other with Poria. "Difficulty," he states, "may be experienced in deciding from poor or scanty material whether a given collection belongs in Merulius or in Poria. The development of the hymenium is, however, fundamentally different in these two genera. In Merulius, the hymenium is at first plane, and in this young stage sections show basidia and spores; by further growth this plane surface is thrown into folds and becomes porose, but it remains continuous over this irregular surface and will show in sections basidia on the edges of the folds as well as lining the pores. In Poria the formation of pores precedes the formation of the hymenium, hence sections of a young Poria having distinct pores may have no basidia as yet."

With reference to *Merulius Ravenelii*, included with the study of the resupinate polypores, Burt remarks: "In its peculiar color and margin, it strikingly resembles *Polyporus haematodus* Rost. (= *Polyporus incarnatus* Karst.) as received from Romell, and which I find in a very scanty specimen under the name *Merulius serpens* in Rabenhorst, Herb. Myc., 6, and Sydow, Myc., March, 3327, but all these European specimens are truly porose from the first, have thick dissepiments, and owe their dark color to dark, incrusting granules upon the hyphae."

P. rufa may prove to be a resupinate form of *Pol. dichrous*, as has already been suggested (3). The waxy consistency of the two plants, the color of the mouths, i.e. flesh to reddish purple, and the spores may be similar in the two fungi. *Pol. dichrous* is usually found on hardwoods, whereas *P. taxicola* occurs on conifers.

Habitat. — *Abies balsamea, Chamaecyparis thyoides, Picea glauca, Pinus attenuata, P. contorta, P. monticola, P. ponderosa, P. taeda, P. resinosa, Thuja occidentalis.*

Distribution. — Ontario, Alaska, Idaho, Iowa, Louisiana, Maine, Massachusetts, Michigan, Minnesota, Montana, New Jersey, New York, Oregon, Pennsylvania, South Carolina.

Occurrence. — In America this plant is found most commonly on spruce, although it is known on other woods. In Europe the species is apparently confined to pine or, at any rate, it is found largely on the wood of this genus.

Poria Johnstonii Murr., Mycologia, 12 : 303. 1920

(Plate VIII)

Type and important specimen:

Poria Johnstonii Murr. on *Pseudotsuga macrocarpa*, Upper San Antonio Canyon, San Antonio Mountains, Southern California. Type. Coll. I. M. Johnston, 252, 1918. Herb. New York Botanical Garden.

Poria Johnstonii Murr. on *Abies amabilis*, Sequoia National Park, California. Coll. Dow V. Baxter, 1936. Herb. Dow V. Baxter.

Fructification effused for several centimeters, inseparable, up to 1 cm. in thickness, becoming somewhat ossified in old plants; margin conspicuous, cottony, snow-white to "ivory yellow"; tubes 0.5–5 mm., usually 0.5–1 mm. long, the longer tubes, i.e. those 4–5 mm. long, breaking up into teeth; subiculum thin; mouths 1–3, mostly 2 to a mm., snow-white when fresh, "ivory yellow" to "maize yellow" in dried specimens; spores (chlamydospores?) cylindrical, 7 × 3–4 μ; capitate cystidia projecting as much as 24 μ and the heads up to 15 × 15 μ large; hyphae of the trama flexuous, occasionally septate and branched, 2 4 μ in diameter, no clamp connections.

Allied species. — In addition to the microscopic features, the cottony margin of the plant, the presence of cottony mycelium in the badly decayed wood, and the somewhat ossified nature (especially when only small tubes are present) of the species when dry are characters to be used in separating it from *Trametes serialis*. *Poria lenis*, which may also exhibit cottony mycelium in the badly decayed wood, is generally a soft plant with pores 3–4, mostly 4 to a mm.

Habitat. — *Abies magnifica, Pseudotsuga macrocarpa.*

Distribution. — California.

Remarks. — Most examples of this very interesting species from California have short tubes (about 1 mm. long), as originally described, and the pores are not ipiciform. The collection made in the Sequoia National Park was extensive enough to show, however, that the tubes may become 5 mm. long and somewhat

ipiciform. In this state the fungus might suggest a resupinate form of a species of Polyporus.

Poria heteromorpha Murr., Mycologia, 12 : 92. 1920

(Plate IX)

Type and important specimen:

Poria heteromorpha Murr., Troy and Tyre, Cockpit Country, Jamaica. W. A. Murrill and W. Harris, 857. Herb. New York Botanical Garden.

Poria heteromorpha Murr. on trunk of *Sabal Palmetto*, Lake George, Florida. Coll. Dow V. Baxter, 1934. Herb. Dow V. Baxter.

Fructification annual or reviving and living through the entire year, whitish, soft to the touch, becoming somewhat corky in age, light in weight, effused in irregular patches often 1 × 3 cm. and usually not over 9 × 6 cm., up to about 5 mm. thick; margin white, thin, arachnoid, up to 2 mm. wide, at first sterile but becoming fertile in age; subiculum white, less than 0.5 mm. thick, inconspicuous; tubes up to 5 mm., mostly 2–3 mm. long; mouths snow-white becoming "cream-buff" to "chamois" in age, 1–3 to a mm., angular; basidia mostly 4 × 11 μ; spores with rough walls, broadly ovoid, uniguttulate, 3–4 × 4–5.5 μ; capitate cystidia projecting about 18 μ, with heads 4–15 × 4–9 μ; hyphae occasionally encrusted; smooth loose hyphae of the trama appearing in the form of loops.

Allied species. — Murrill (7) states that this species reminds one of *Lenzites heteromorpha.* There is some suggestion of the latter in old, revived plants which appear irregular in form because they have grown over the rough surface of the old fruiting structure and have, furthermore, become corky in age. I find, however, that the plant resembles *Poria mollusca* (of contemporary Swedish interpretation) much more closely. The soft texture of young plants, the color when fresh, and the color in old specimens are certainly similar in the two species. *P. mollusca,* however, does not become strictly coriaceous in age. Many examples of it are conspicuously rhizomorphic, whereas *P. heteromorpha* exhibits a cottony margin. The tubes of *Trametes* (*Lenzites*) *heteromorpha* are coarse and have larger mouths than those of *P. heteromorpha.*

Habitat. — *Sabal Palmetto.*

Distribution. — Florida. (Found also in Jamaica and Porto Rico.)

Remarks. — It is unfortunate that the name *Poria heteromorpha* has

been given to this plant, since, superficially, certain old specimens of the poria bear some resemblance to *Trametes heteromorpha*. Furthermore, *T. heteromorpha* occurs in the resupinate state so frequently that one might not only find the two names confusing but might at first believe them actually synonymous. The microscopic features, however, show that *P. heteromorpha* and *T. heteromorpha* are not even related.

Poria coniferarum, sp. nov.

(Plate VI, Fig. 1)

Type and important specimen:

Poria coniferarum, sp. nov., on *Pinus monticola*, Priest River, Idaho. Type. Coll. J. R. Weir, Sept., 1914. Herb. Mo. Bot. Gard. 55998.

Poria coniferarum, sp. nov., on *Pinus monticola*, Coolin, Idaho. Coll. J. R. Weir, Sept., 1919. Herb. Mycolog. Lars Romell, Stockholm.

Fructificatio effusa, tenuis, diam. plus minusve 15 cm., fragilis, plerumque minus quam 0.3 mm. crassa, margine tenui-aranea, pallide grisea vel purpureo-grisea vel pallide olivaceo-ochracea; foraminibus brevibus hucusque ad marginem terminata; tubi vel recti ca. 0.5–1.5 mm. longi vel si obliqui plerumque hucusque ad 5.5 mm. longi, recentes lilacinei vel pallide grisei vel immaturi argillaceo-straminei siccitate vel avellanei vel argillaceo-ochracei; aperturae 1–2 in uno mm.; basidia plerumque $9 \times 4\ \mu$; sporae subglobosae vel cylindricae, muribus leviter asperulis vel spinosis, $5–7 \times 4\ \mu$; cystidia nulla; hyphae hyalinae; anastomoses adsunt. Specimen typicum in Herb. Mo. Bot. Gard. conservatum: Legit prope Priest River, Idaho, J. R. Weir, Sept., 1914. Herb. Mo. Bot. Gard. 55998.

Fructification effused in thin patches for 15 or more cm., fragile, mostly less than 0.3 mm. thick; margin thin, arachnoid, "pale gray," "pallid purplish gray" to "pale olive-buff," becoming chambered with shallow pores; tubes mostly 0.5 1.5 mm. long, up to 5.5 mm. long when arranged obliquely, lilac to gray or clay-yellow when fresh, drying to "avellaneous" to "clay color"; mouths 1–2 to a mm.; basidia mostly $9 \times 4\ \mu$; spores subglobose or subcylindrical, with slightly roughened or echinulate walls, $5–7 \times 4\ \mu$; no cystidia; hyphae collapsed, sometimes encrusted, 2–5.5 μ in diameter, clamp connections present.

Allied species. — This poria suggests some forms of *Poria reticulata*,

but it can be readily separated from that species by its spores. Another allied plant is *P. bombycina* Fr. (*Pol. hians* Karst.). Difficulty may be found in separating it unless one has record of its color when fresh — pale purplish or lilac — and unless mature plants with fully developed tubes are available for study. The long tubes of the new species should readily separate it from that poria. In the dried state the color of *P. coniferarum* is similar to that of herbarium specimens of *P. myceliosa.* The latter species is widely effused over the surface of the substratum and has a broad sterile fimbriate border.

Habitat. — *Pinus contorta, P. monticola.*

Distribution. — Alberta, Idaho.

Poria cryptacantha Mont., Cent. 7, p. 37, in Sacc., p. 329. 1888

(Plate VII, Fig. 2)

Fructification annual or perennial, effused for 1 meter or more on bark of old logs, generally separable, up to 3 mm. thick, but mostly less, and varying with the irregularities of the substratum; margin up to 1.5 mm. wide, at first tomentose, "clay color" in young plants, "pallid mouse gray" in old specimens, becoming fertile in age; subiculum conspicuous, felty, soft and punky, "clay color"; tubes 2 mm. long or less and often only 0.5 mm. in length, rarely stratified, but sometimes receding growth habit exhibited; mouths "chestnut-brown" or "wood brown," circular to angular, fringed, 4–5 to a mm.; spores globose or subglobose, 3 × 3 μ (not found attached); hyphae brown, 2–3 μ in diameter, not branched, no clamp connections; setae 13–37 × 4–7 μ.

Allied species. — *P. cryptacantha* most nearly resembles *Fomes nigrolimitatus* because of its soft and punky context. But it is a thinner plant and differs also in its brown shades. *F. nigrolimitatus* is a western conifer-inhabiting plant, whereas *P. cryptacantha* has been found only on hardwoods in the southern part of the United States and in South America. Unfortunately, the spores of *P. cryptacantha* are not definitely known, and the two species cannot be contrasted with any degree of certainty in this character. No attached spores have been found in species studied, but spores in

the mounts made from this plant are 3 × 3 μ. Those of *F. nigrolimitatus* are cylindric, 4–6 × 1.5–2 μ.

The habit of growth and even the color of *P. cryptacantha* suggest *F. conchatus*, but *F. conchatus* is much more woody than the plant described here.

Habitat. — On hardwood logs.

Distribution. — Florida. (Also known from Brazil.)

Fomitiporella floridana Murr., North Am. Flora, 9:14. 1907

Type and important specimens:

Fomitiporella floridana Murr. on deciduous wood, Florida. Type. Coll. W. W. Calkins, 850. Herb. N. Y. Bot. Gard.

Fomitiporella floridana Murr. on *Quercus nigra* Strain I, Walterboro, South Carolina. Coll. Dow V. Baxter. Herb. Dow V. Baxter.

Fomitiporella floridana Murr. on *Quercus phellos* Strain II, Arkansas. Coll. Dow V. Baxter. Herb. Dow V. Baxter.

Fructification perennial, effused in patches up to 45 cm. long, woody, up to 2 cm. thick; margin mostly less than 0.5 mm. wide, at first "wood brown," becoming blackish in age; context "cinnamon-brown," less than 0.5 and usually less than 0.3 mm. in thickness; tubes 2–3 mm. long each season, stuffing whitish; mouths angular, 5–7 to a mm., grayish umber with a distinct sheen which suggests that of *Fomes Everhartii*, the brown colors being "snuff brown," "Verona brown," "bister"; dessipiments thin, entire or uneven; basidia 7 9 × 3 5 μ; spores globose, smooth, at first hyaline, becoming pale ferruginous, 4 × 3–4 μ; hyphae ferruginous; no cystidia in specimens of Strain I (none in type); cystidia present in Strain II, 13–20 × 5.5–7 μ.

Allied species. — *F. floridana* is distinctive among the Fomitiporellae and Fomitiporiae because the pore surface most closely resembles that of *F. Everhartii*. Descriptions of *F. floridana* are misleading, however, and one is apt to confuse it with *Poria pereffusa*, which has "glistening" tubes. Macroscopically *P. pereffusa* more closely resembles *Poria betulina* or *Fomes igniarius* var. *laevigatus*, according to type specimens. Microscopically it differs from these two plants by its colored spores. *Fomitiporella melleopora*, also, is described as having mouths "flavous to melleous," a phrase which suggests a glistening pore surface. *F. melleopora* (type) is

much more yellow, "old gold," than *F. floridana*, which in its browns is more nearly similar to *P. betulina* or *F. igniarius* var. *laevigatus*.

Cultures. — Isolated from *Quercus nigra* Strain I, Walterboro, South Carolina, and from *Quercus phellos* Strain II, Arkansas. Both strains are characterized by such an abundant development of mycelium in cultures that the fungus almost fills the flasks. Strain I belongs to the slow-growth class and falls into the large range of temperature and the high-temperature groups. It grows best in the dark. Strain II differs from Strain I in that it has no black-line formation, it is lighter in color, and it is not so nodulose. It is, furthermore, cottony rather than chamois-like.

Habitat. — *Quercus nigra, Q. phellos.*

Distribution. — Arkansas, Florida, South Carolina.

Remarks. — Attention is called to the fact that there is a morphological difference existing between Strain I and Strain II. Strain II possesses cystidia, but is otherwise microscopically and macroscopically identical with the type. The likeness of the cultures in their habit of forming an abundant growth of mycelium is important.

Poria reticulata (Pers.) Fr., Syst. Myc., 1:385. 1830. In Sacc., p. 330. 1888

Polyporus expallescens var. *flavidulus* Karst. ex Romell.
Polyporus farinellus Fr. ex Romell.

Important specimens:
Poria reticulata Fr. Leg. Bresadola, 1895. Herb. Bresadola, Stockholm.
Poria reticulata Fr. Leg. Romell, 1910. 13241. Herb. Myc. Lars Romell, Stockholm.

Fructification annual, appearing in irregular areas, effused for about 10 cm., adnate, extremely thin, less than 0.3 mm. thick, fragile; margin up to 1.5 mm. wide but mostly 0.5 mm. or less, cobwebby or becoming fertile, "pale olive-buff"; subiculum thin, paper-like, "pale olive-buff"; tubes shallow, rarely as much as 1 mm. and usually less than 0.3 mm. long, somewhat merulioid; mouths 2–4 to a mm., round to angular, white at first then "pale olive-buff," "cream-buff" to "pinkish buff"; dissepiments 62–220 μ wide; basidia 4-spored, 15–20 × 6–7 μ; spores allantoid, 6–10 (7–9 × 2.5–3) 2–3.5 μ; hyphae hyaline, fragile, loosely arranged,

smooth or encrusted, occasionally septate, much-branched, 2–5 μ in diameter.

Allied species. — *Poria reticulata* may suggest a poorly developed form of *P. versiporus* or, at least, one exhibiting short tubes. *P. candidissima* and *P. corticola*, also, may be confused macroscopically with this species. The large, long spores of *P. reticulata* are very distinctive and set it apart from these plants.

Occurrence. — This interesting species, which is frequently found on frondose wood in Sweden, is common on willow in the Alaskan tundra. It seems to occur more frequently here than in the United States.

Habitat. — *Pinus echinata, Picea sitchensis, Populus balsamifera, Salix sp., Sequoia sempervirens, Tsuga heterophylla.*

Distribution. — Alberta, British Columbia, Manitoba, Alaska, California, Florida, West Virginia.

Poria nigrescens Bres., Atti Accad. Rovereto, III, 3 : 83. 1897

Type and important specimen:

Poria nigrescens Bres., sp. nov., on coniferous trunk. Leg. Bresadola. Herb. Bresadola, Stockholm. 1898.

Poria nigrescens Bres., sp. nov., on *Abies pectinata*, Prencow. Kmet, 1889. Herb. Bresadola, Stockholm.

Fructification perennial, effused in patches 1-6 cm. broad and 9 cm. or more long, averaging 2–4 mm. thick, separable; margin at first less than 0.5–1 mm. wide, slightly pubescent, often becoming fertile, loosening from the substratum upon drying; subiculum distinct, less than 0.5 mm. thick, white when fresh, "cream-buff" in herbarium specimens; tubes distinctly stratified, usually exhibiting a receding growth habit, i.e. new growth often not covering all the old fructification, 1.5-6 mm. long each season; mouths flesh-color when fresh, "pale pinkish cinnamon," "pinkish buff," "cinnamon-buff" to "deep mouse gray" when dry, subcircular to angular, rather thick walls, 5-6 to a mm.; dissepiments entire; basidia 4-spored; spores hyaline, globose or broadly ellipsoidal, 3 5 μ; hyphae hyaline, mostly coarse, thick-walled; simple hyphae 2–7 μ in diameter, cross walls evident, no clamp connections and no cystidia.

Allied species. – The relationship of this plant to *Polyporus rigidus*

Lév. has been mentioned by Overholts (8). Attention is called to the fact that in cross sections of the hymenium of both plants the trama is seen to be very compact, the sections of the closely crowded, thick-walled hyphae giving a "pseudo-cellular" appearance. It is pointed out that *Pol. rigidus* does not become noticeably darker or smoke-colored on drying, nor is it perennial.

Habitat. — *Betula sp., Fagus americana, Ilex opaca, Liquidambar styraciflua, Thuja plicata, Tsuga canadensis, Ulmus americana.*

Distribution. — Ontario, Alaska, Arkansas, California, Florida, Idaho, Illinois, Indiana, Louisiana, Michigan, New Hampshire, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Vermont, Virginia, West Virginia.

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PLATES I–IX

Poria luteofibrata, sp. nov., on *Pinus rigida serotina*, Lake City, Florida

Poria luteofibrata, sp. nov., on *Pinus rigida serotina*, Olustee Forest Experiment Station, Florida

FIG. 1. *Poria luteofibrata*, sp. nov., on *Pinus rigida serotina*, Olustee Forest Experiment Station, Florida. Note rhizomorphs

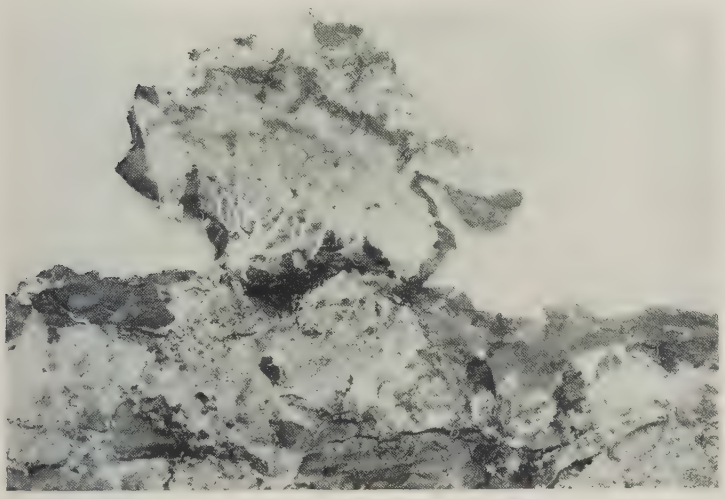
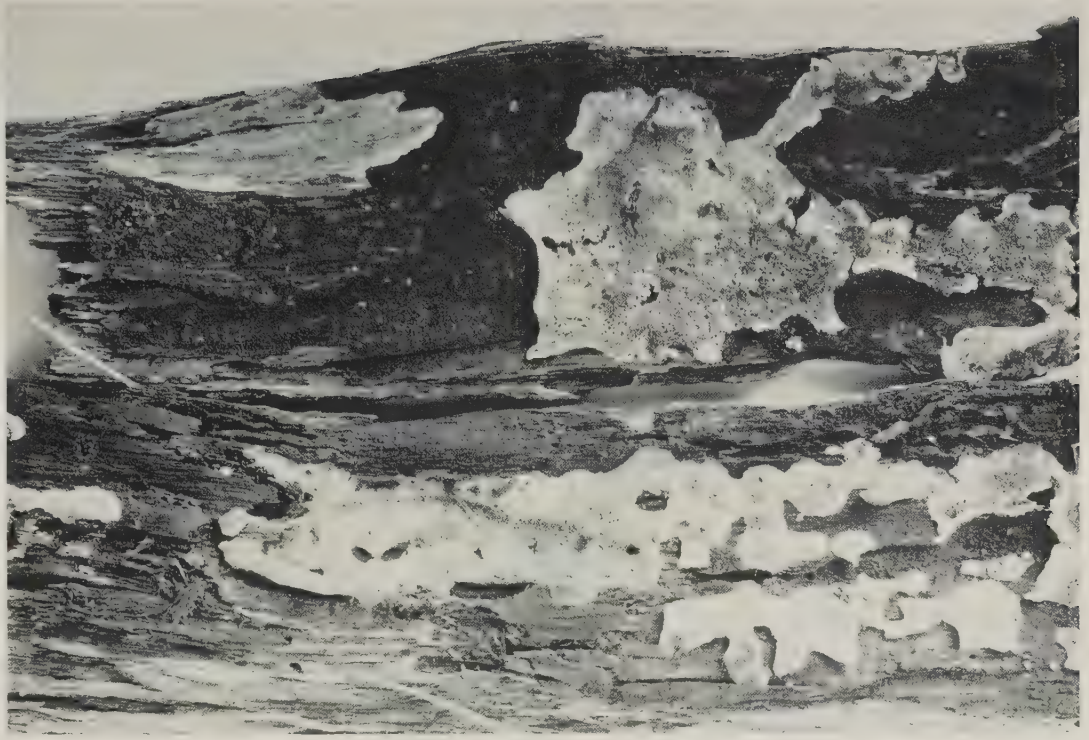


FIG. 2. *Polyporus flavovirens* on *Pinus silvestris*. Named by Lars Romell. Herb. Mycolog. Lars Romell 13188. Stockholm, Sweden



Poria albipellucida, sp. nov., on *Thuja plicata*, Vancouver, British Columbia

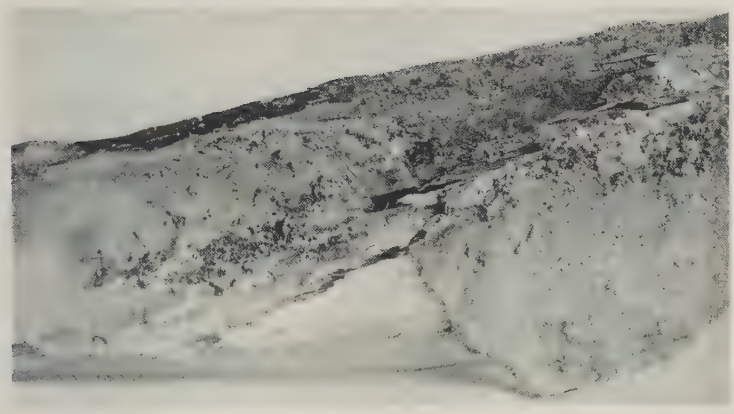


FIG. 1. *Poria sitchensis*, sp. nov., on *Tsuga heterophylla*, Sitka, Alaska

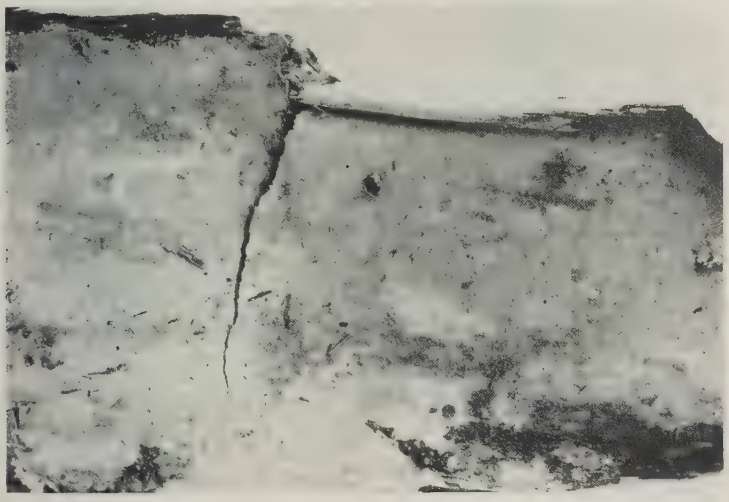


FIG. 2. *Poria sitchensis*, sp. nov., on *Picea sitchensis*, Sitka, Alaska

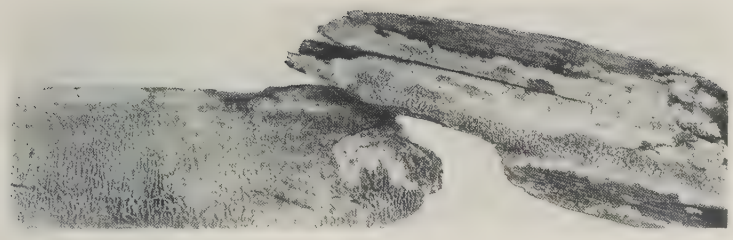


FIG. 1. *Poria coniferarum* on *Pinus monticola*, Priest River, Idaho

FIG. 2. Ten-month-old culture of *Poria sitchensis*, sp. nov., on basswood blocks

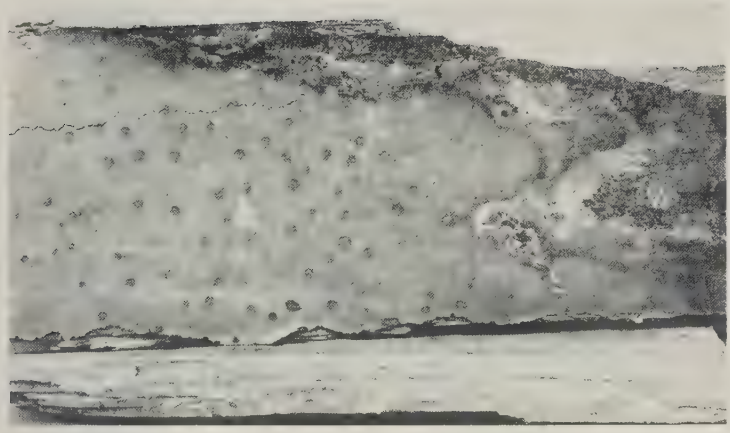
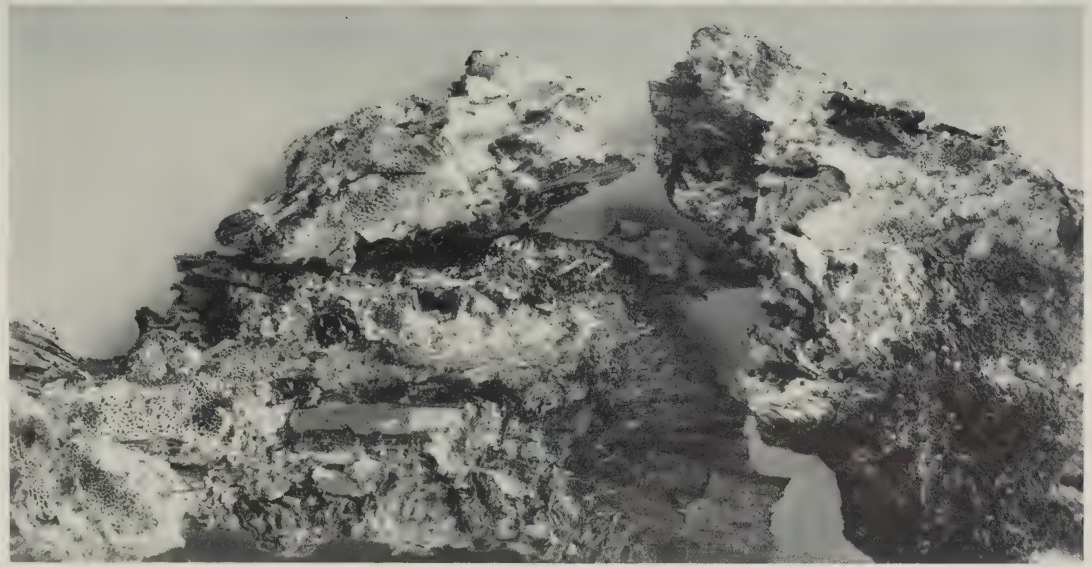


FIG. 1. *Poria sitchensis*, sp. nov., on *Pinus monticola*, Priest River, Idaho

FIG. 2. *Poria cryptacantha* Mont., Ft. White, Florida



Poria Johnstonii Murr. on *Abies magnifica*, Sequoia National Park, California

Poria heteromorpha Murr. on *Sabal Palmetto*, Lake George, Florida

THE INFLUENCE OF SOIL TREATMENT ON JACK-PINE REPRODUCTION

RUSSELL K. LeBARRON AND FRANCIS H. EYRE

JACK PINE, commonly known as a tree of the sand plains, occurs also, in some parts of its range, on heavier, more fertile soils. On these soils, considerable areas of which are found in northeastern Minnesota and adjacent Ontario, this species is not maintaining itself. In natural stands over eighty years of age it is dying out rather rapidly and is being replaced by hardwood shrubs, balsam fir, and paper birch, with a sprinkling of black spruce, white spruce, and white pine. Logging speeds up the conversion to inferior species, especially aspen and paper birch (1).

Since jack pine is more valuable than are the chief components of the forest type that is replacing it, foresters are interested in learning how to encourage natural reproduction of this species. An experiment in seedbed preparation started on the Superior National Forest in 1934 by the Lake States Forest Experiment Station has helped to clear up certain phases of the problem.

Before discussing this experiment, it would be well to consider briefly how jack pine has managed to attain its present dominant position on the heavier soils where other species are more at home. Unlike most forest trees, it does not shed much of its seed at the time it ripens. Instead, by far the greater part of the seed remains in the persistent cones more or less permanently sealed up until released by a forest fire.

Although practically all vegetation is killed when a fire sweeps through a jack-pine stand, the seed, owing to the insulation afforded by the thick-scaled cones, remains unharmed. The heat of the flames, usually not of long enough duration to destroy the cones, opens the scales, permitting a tremendous quantity of seed to drop on soil which is practically bare. Thus it is that the dense jack-pine stands of the Superior National Forest have originated. It is apparently only in such a way that this species can perpetuate itself on

these heavier soils where other species are better equipped to maintain themselves.

Although jack pine in the absence of fire disperses little seed, it has been shown by Eyre (2) that large quantities of seed will be released if the cone-bearing slash remaining after a logging operation is scattered over the ground and left during a part or all of a summer season. But the mere presence of seed has been insufficient to insure adequate regeneration. It was thought that soil treatments to improve seedbed conditions might prove of value in accomplishing this purpose, since the tough and fibrous mat of duff which tends to build up more on heavy soils than on sandy soils appeared to be a poor medium for the development of tree seedlings. This idea, therefore, serves as the foundation for the experiment reported here.

The stand of timber chosen for the location of the experiment covered about nine acres and consisted of heavily stocked seventy-year-old jack pine, with an admixture of black spruce, paper birch, and aspen. The topography is almost level; the soil is a layer of good quality loam about two feet deep covering igneous bedrock. The duff and humus layer under the stand was from one to four inches thick and rather poorly decomposed. It was strongly bound together by the roots of live plants and proved to be difficult to remove even with the aid of mattocks.

The first step in the experiment was to remove the duff with mattocks and rakes. This was done on some parts of the tract; on others it was merely torn up, but left in place. Some portions, also, were retained undisturbed for comparison. This work was carried out in October, 1934.

In February of the following winter three acres were cut clear, half of the trees were removed from five acres, and one acre was left uncut. The plots were so arranged that all three methods of soil treatment occurred on both the partly cut and clear-cut plots. On the uncut plot the duff was undisturbed.

At the time of cutting the branches of the felled trees were lopped and scattered. The following summer half of the clear-cut plot was broadcast-burned when the slash had become dry enough to burn readily.

The jack-pine reproduction resulting from the experiment, based on counts made in August, 1936, two growing seasons after cutting, is shown in Table I.

TABLE I

NUMBER OF JACK-PINE SEEDLINGS PER ACRE AS A RESULT OF DIFFERENT SOIL TREATMENTS AND DIFFERENT DEGREES OF CUTTING*

Soil treatment	Degree of cutting			Basis (number mil-acre quadrats)
	Uncut	Partial cutting	Clear-cutting	
No treatment.....	20	160	711	121
Duff torn up.....	..	550	930	62
Duff removed.....	..	2,520	10,025	90
Basis (number of mil-acre quadrats)	50	140	83	273

* Considerable numbers of aspen suckers and seedlings of aspen, paper birch, black spruce, and balsam fir also came in on the various plots, but these are not included here since they are not pertinent to the discussion.

As will be noted, adequate reproduction was not obtained in any case on the undisturbed forest floor, although there was an increase in the number of seedlings with the degree of cutting. It should be pointed out that this increase may have been due entirely to the quantity of seed which reached the ground. Certainly most of the seed must have come from the cones in the slash, which, on the clear-cut area, was twice as heavy as on the partly cut plot from which only 50 per cent of the stand had been removed. Thus the clear-cut plot was, no doubt, seeded twice as heavily as the partial cutting. The same trend is evident in the figures given for the areas that were treated.

The striking result, however, was the tremendous increase in reproduction on the clear-cut plot where the duff layer had been completely removed. This amounted to over 10,000 seedlings per acre.

The broadcast burning of the slash was not successful; the seedlings on this plot now number only 1,782 per acre, which is far from being ideal stocking when their age and patchy distribution are considered. The apparent reason why a forest fire will start a jack-pine stand, but a slashing fire will not, is that the heat of a slashing fire is much more intense and longer in duration around the cones. In the case of the forest fire, the heat merely opens the cones in the tree-

tops, but in a slashing fire most of the cones, together with the seed, are actually consumed. It is conceivable, of course, that a very light fire could be run through slashings, but in the one such attempt which was made the fire was too hot to achieve the desired end. Before definite conclusions can be drawn on the practicability of using fire to release jack-pine seed and prepare the seedbed additional experiments must be conducted. It is clearly evident, however, that it is necessary to expose the mineral soil in some manner if jack-pine reproduction is to be obtained on heavy soils.

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HISTORY OF BLISTER-RUST CONTROL IN MICHIGAN

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ACTIVITIES in white pine blister-rust control have been conducted as a coöperative project in Michigan. The original agencies were the Bureau of Plant Industry in the United States Department of Agriculture and the state inspector of orchards and nurseries in Michigan, who, in turn, had the assistance of the officials of the Michigan Agricultural College, the University of Michigan, and the state forester. In 1921 the office of the state inspector of orchards and nurseries was discontinued, and the Michigan State Department of Agriculture, through the commissioner of agriculture, became and still is the coöperator. In 1929 the legislature passed Act No. 313, known as the white pine blister-rust control act, which empowers the commissioner of agriculture to pursue the control of blister rust by destroying either of the host plants, namely, diseased pine or currant and gooseberry bushes (Ribes), and authorizes him to act in conjunction with the United States Department of Agriculture, the Michigan Department of Conservation, counties, townships, associations, and individuals in the suppression and control of the rust. During the last three years the United States Department of Agriculture has collaborated through its Bureau of Entomology and Plant Quarantine.

Blister rust was first found in Michigan in 1917 on imported white pine planted in Oakland County and, later, on imported white pine planted in Kent County. These trees were promptly destroyed, but not before the disease had gained a foothold in the state. In 1928 it was discovered on native white pine in Cheboygan County and in 1929 in Marquette and Dickinson counties. Since then it has been found on pine in Baraga, Iron, Menominee, Houghton, Ontonagon, and Delta counties in the Upper Peninsula and in Mason, Iosco, Kent, Oceana, Leelanau, Sanilac, Ottawa, Emmet, Otsego, Alcona, Newago, Montcalm, and Benzie counties in the Lower Peninsula. By 1936 infection on Ribes had been found in all the

fifteen counties of the Upper Peninsula and in forty counties in the Lower Peninsula. With this ever-increasing spread of the rust no stand of white pine growing in Michigan can be considered safe from attack and damage so long as large numbers of Ribes are growing among and near the trees.

The early work in Michigan was carried on through the efforts of Pennington, Pierce, Posey, Young, and Baxter, representing the Federal authorities, and local scouts hired during the summer months. The initial activities were scouting, tracing down the importations of white pine planting stocks, and carefully inspecting all plantations of white pine to determine the presence or the absence of the disease. The first really intensive work was carried on by Baxter and others in Kent and Oakland counties. In 1927, under a coöperative agreement with the United States Department of Agriculture, the first agent for all-year blister-rust control was employed, and a survey of pine areas was begun, in which the help of school children was obtained in many counties. Through this survey some excellent results were secured at a very small cost. Late in 1927 Messrs. Hodgkins, Sheals, and Corliss of the United States Department of Agriculture were sent to Michigan, and infections were found on Ribes all through the "Thumb" district and in a belt two counties wide straight west of Saginaw and Bay City. In 1928 Mr. Corliss observed the first infection on native pine at Indian River in Tuscarora Township in Cheboygan County, and within a few weeks interest was so aroused in this district that the Tuscarora Township Board appropriated $500 to carry on local control work, the first intensive local control on a large scale in the state.

In 1929 came the enactment of the state blister-rust control law and the appropriation of $20,000 for each of two years. It was during this biennium that the first systematic work in eradicating the cultivated black currant was started.

During 1930 and 1931 many private owners of pine were interviewed, and as a result considerable help was obtained. In this setup pine owners provided the labor while the state and Federal governments furnished the supervision and assumed responsibility for the quality of the work. It was within this period that the first nursery-sanitation work was done in the state-owned nurseries, where millions of white pines were growing.

In 1932 a small state appropriation matched by Federal funds

was made available, and county labor provided by the local authorities was first used on the project. Late in 1933 the first control work was begun under the National Industrial Recovery Act. In this same year local control under the program of Emergency Conservation Work started, and before the year ended the Civil Works Administration activities, chiefly in cultivated black currant eradication, were carried on.

The program of the National Industrial Recovery Act, the Emergency Conservation Work, and the Civil Works Administration reached the peak in 1934, when 1,240 men were employed. Throughout the year activities were also continued in a few counties under funds of the Federal Emergency Relief Administration.

In 1935 the first funds under the Works Progress Administration for control work were allotted. The program of the Civilian Conservation Corps, which attained maximum size in 1934, was greatly decreased, but the Works Progress Administration program went to a new high in September, when 1,284 men were on the rolls.

Before summarizing the results I wish to touch on the various kinds of activities included under blister-rust control. The late fall preëradication survey work is done by the trained supervisory personnel. In it the white pine stands are located on maps which are drawn to a scale of four inches to the mile. In evaluating pine stands the following standards have been set up in agreement with state and Federal foresters for first priority pine:

TABLE I

Evaluation of Pine Stands

Character of stands	*Size of area*	*Minimum stocking for the areas*
1. Ornamental pines public parks, resorts	Any size 5 acres	One or more groups 20 pines per acre
2. Native stands in forest areas	20 acres	1–6 ft. high, 200 pines per acre; 7–15 ft. high, 100 pines per acre; 16 ft. and up, 50–75 pines per acre
3. Woodlots	5 acres	50 pines per acre
4. Planted pines	1 acre	500 pines per acre
5. Shelter belts	Any size	10 or more pines

In Michigan, Wisconsin, and Minnesota there are large areas of white pine which do not meet the minimum requirements for good white pine, but which contain within themselves sufficient trees to justify limited protection costs or which are in process of producing well-stocked stands by virtue of being seed trees. These stands, which we may describe as "second-priority pine," may be given a set of minimum requirements. Such requirements would apply to native stands in forest areas of 20 acres or more, with the following number of pines per acre in the different size classes:

50 pines per acre ..... 1–6 feet high
25 pines per acre ..... 7–15 feet high
15 pines per acre ..... over 15 feet high

In protecting first-priority pines a zone of 900 feet is worked around each stand on all land, with the exception of live swamp, where eradication is limited to a narrow border extending into the swamp for a distance of 200 feet. In protecting second-priority pines a zone of 900 feet is worked around each stand, with the exception of live swamp, which is left untouched. A small amount of crew work is being done in the protection of such stands.

All mapping is tied in very closely with the standard practice of the United States Forest Service. The real purposes of the preëradication survey are not only to locate pine areas, but to give a basis for making fairly accurate estimates of the amount of effort necessary to protect the pine.

Since this work is done extensively in the fall and winter difficult conditions, naturally, are apt to be encountered, among them deep snow, which prevents observation of ground cover. To assist the mappers in working up their estimates a list has been made of the Ribes types common to the Lake States. These types, which denote the conditions indicative of the degree of Ribes abundance, are given in Table II.

As soon as Ribes leaves make their appearance we are ready to start a second phase, known as local control. Local-control crews, properly supervised and using the preëradication survey maps, commence systematic removal of all Ribes under white pine and within a 900-foot zone all around the stand. Blister-rust agents teach their foremen to recognize the different types of Ribes native to the region by their leaf characteristics and habit of growth, and these foremen later teach and develop the workers so that they may become skilled

TABLE II

Types of Ribes in the Lake States

	Ribes type and name	Character	Ribes species	Ribes abundance
A	Swamp type: cedar, hardwoods, alder, tamarack, black spruce	Water usually flowing, deep humus, loamy soil, much brush, windfalls, cedar hardwoods, white pine scattering. Usually difficult, costly eradication job. Crew work. Close formation	R. hirtellum (smooth gooseberry) R. americanum (wild or American black currant) R. triste (swamp red currant) R. hudsonianum (Hudson Bay currant) R. glandulosum (skunk currant) R. cynosbati (prickly or pasture gooseberry or dogberry) R. oxyacanthoides (smooth gooseberry) R. missouriense (Missouri gooseberry)	Heavy
B	Swamp type: muskeg	Water still, deep peat, dense growth, leatherleaf, moss, scattered dwarf black spruce. Scout or crew work at edges only	R. glandulosum (skunk currant)	None except at edges
C	Upland type: hardwoods, white pine	Dry land, medium duff, sandy loam to clay loam, good soil, brush medium, mixed hardwoods, white pine, open aspen, birch, good white pine planting sites. Crew work	R. hirtellum (smooth gooseberry) R. cynosbati (prickly or pasture gooseberry or dogberry) R. oxyacanthoides (smooth gooseberry) R. triste (swamp red currant)	Medium to heavy
D	Upland type	Dry land, sand to sandy loam, brush light, jack pine, Norway pine, white pine, white pine planting site. Usually scout work	R. triste (swamp red currant) R. cynosbati (prickly or pasture gooseberry or dogberry) R. hirtellum (smooth gooseberry)	None to few

TABLE II (*Concluded*)

Ribes type and name	Character	Ribes species	Ribes abundance
E Upland type: pasture	Dry land, open fields, pastures. Soils vary. Scattered hardwoods, white pine. Scout or crew work	R. cynosbati (prickly or pasture gooseberry or dogberry) R. hirtellum (smooth gooseberry) R. americanum (wild or American black currant) R. missouriense (Missouri gooseberry)	Few to medium: often large bushes
F Cultivated	Area in crops or meadow and not needing even scout work, except along fences, stone piles, etc.	None	None

in spotting Ribes under all conditions met in the forests. When the men have developed a "Ribes eye" they are trained in the methods of pulling and hanging the bushes so that they will not sprout again. Of course, in eradicating the plants great care must be exercised to remove all the crowns and the large roots. Under the eradication program it is necessary that every square foot be covered, and in order to avoid missing any of the ground the area is worked in strips by the Ribes crews, usually composed of five men abreast, followed by a straw boss. The foreman runs out a string line marking the boundaries of the area to be worked. Then the straw boss starts his crew at right angles to this line. One of the end men carries a ball of one-ply string, allowing it to unwind as he walks along. When the crew reaches the end of the strip, it turns around and follows back along the line just laid, and the other end man lays the line along the new strip. The distance between the men ranges from 4 to 20 feet, depending upon the density of the Ribes and of the cover.

The local-control crews are required to reduce the live stem to 25 feet per acre. Careful checks are made by the foremen and supervisors to see that this standard is closely observed.

The nursery-sanitation program follows closely the procedure

laid down for Ribes eradication in pine stands, with the exception that where Federal permits are requested by the nurseries the crews usually work the area several times, each time going in a direction at right angles to the previous working and reducing the live stem practically to zero before certificates are issued. This work is checked not only by the state organizations but also by a representative from the Division of Domestic Plant Quarantines of the Federal Bureau of Entomology and Plant Quarantine.

A large number of species of Ribes have been found by the workers. In the wild gooseberry group *Ribes cynosbati* (prickly or pasture gooseberry or dogberry), *R. hirtellum* (smooth gooseberry), and *R. oxyacanthoides* (smooth gooseberry) have been noted; in the wild currant group *R. americanum* (wild or American black currant), *R. triste* (swamp red currant), *R. glandulosum* (skunk currant), *R. hudsonianum* (Hudson Bay currant), and *R. lacustre* (swamp black currant). In the cultivated gooseberry group there are found the various strains of *R. grossularia* (European or English gooseberry); in the cultivated currant group, the various strains of *R. vulgare* (red currant of gardens), *R. aureum* (slender golden currant), *R. odoratum* (Missouri or golden or buffalo currant), *R. alpinum* (mountain currant), and *R. nigrum* (black currant or European black currant). Most of the indigenous species are pretty well known. There is, however, still much to be learned about them. I doubt whether any species of Ribes have escaped the notice of our botanists, but the recorded ranges of some of the species have been considerably extended by our workers. We need better keys than are generally available to our laymen, and I am happy to be able to say that, with the aid of the Department of Botany of Michigan State College, some progress is being made in that direction.

One of the very important control activities which have been given considerable weight in Michigan is the eradication of the cultivated black currant, *Ribes nigrum*. Because of its extreme susceptibility to infection and because the volume of spores produced on it is capable of causing severe damage to pine, this currant is the most potent factor in the long-distance spread of the rust.

A summary of local control as of December, 1936, follows:

Acres in protective zone worked over once	725,455
Acres in protective zone worked over a second time	33,453
Number of wild Ribes eradicated	92,282,179

Michigan has 545,218 acres of white pine worth protecting, and of this area 256,758 acres have been worked once and 14,385 have been reworked. Approximately 46 per cent of the acres of white pine have been given initial protection.

In the nursery-sanitation activity from 1929 to 1936, inclusive, seven nurseries have been protected from infection, three being state nurseries and four government-owned. Crews have worked 3,445 acres and have pulled 1,015,649 wild Ribes in the vicinity of such nurseries; 137 cultivated black currants have been eradicated because they were within the one-mile limit of the edge of the nurseries.

The black currant eradication has been conducted in sixty-one counties, where 10,842 locations were found to have *Ribes nigrum* growing on them, and 108,727 plants of this species have been eradicated. A large concentration was removed from Chippewa, Houghton, and Marquette counties, in which 43,788 bushes were eradicated.

At the close of the year 1936 Ribes infection had been found in fifty-five counties in the state and white pine infection in twenty-eight counties. All counties of the Upper Peninsula are known to have blister-rust infections, and all in the Lower Peninsula north of a line drawn from Allegan in the southwest corner to Gratiot and back to Oakland in the southeast corner, with the exception of seven counties in the dry jack pine area of the northern part of the Lower Peninsula.

That we may have some idea when it is necessary to give white pine areas the second protection, forty-six permanent plots for the study of Ribes regeneration, each one fiftieth of an acre, have been established prior to eradication. Forty-one have been laid out in the live swamp type and five in the upland type, where hardwoods and white pine grow. These plots are examined every year to determine the rate of regeneration.

Plots have also been laid out in several sections of the state where blister rust has done considerable damage to white pines. They are being used not only as experimental plots for the study of pine infection but as demonstration areas so that the public may better appreciate the seriousness of the disease. All are easily accessible, and those interested in seeing the various areas are urged to get in contact with our state or district leader, who will be glad to accompany them.

Lansing, Michigan

ADMINISTRATIVE ASPECTS OF THE APPLICATION OF THE DISCOUNT PRINCIPLE IN THE ASSESSMENT OF FOREST PROPERTY

DONALD M. MATTHEWS

FOR a considerable period the discount principle has been used by the Michigan State Board of Tax Commissioners in the valuation of mineral properties. With certain modifications it could be applied to the assessment of forest property with equally satisfactory results. The objectives of assessment by this principle would be: (1) to determine a value for tax purposes which would be closely related to the income which the owners of the property would receive from it under the plan which they might adopt for managing the property; (2) to determine such values in a manner which would make certain that the tax would take the same percentage of net income in all cases; and (3) to stabilize tax income by fixing the tax levy at an amount which would not change during the life of the plan under which the assessment had been determined unless basic values or tax rates changed.

The formula which has been suggested for use in determining such an assessment is as follows:

$$P = \frac{A}{0.0i + 0.0t + \frac{0.0s}{(1.0s^n - 1)}},$$

in which

P = the present worth;
A = the annual net income (without deduction for taxes) during the period under consideration;
i = the capitalizing rate or rate of interest that the investment is expected to earn;
t = the rate of taxation;
s = the rate of interest earned by the depletion fund which at the end of the operation is to equal the present worth of the property;
n = the number of years in the period under consideration.

As an illustration of the way in which the formula would work with a liquidating timber operation, we may assume that a timber property

of 40,000 acres, carrying a stand of 515,640 M ft. b. m. is to be operated under a plan which would completely liquidate the timber in twenty years and yield an average annual net income from stumpage of $163,320 before taxes. The land might be assessed at any figure considered reasonable in comparison with bare land values in the vicinity, but with capitalizing and sinking fund rates fixed at 6 per cent and the tax rate at 1.5 per cent, the assessment of the timber would be as follows:

$$P = \frac{\$163{,}320}{0.06 + 0.015 + \dfrac{0.06}{(1.06^{20} - 1)}}, \quad \text{or} \quad \frac{\$163{,}320}{0.06 + 0.015 + 0.0272}$$

and, solving,

$$P = \$1{,}598{,}000.$$

This is the capital sum of money:

(*a*) Upon which income will pay a tax calculated at 1.5 per cent for 20 years, an annual sum of	$ 23,970
(*b*) Upon which income will pay interest at 6 per cent for 20 years, an annual sum of	95,880
(*c*) That will be duplicated in 20 years by an annual depletion fund payable from income accumulating at 6 per cent interest of	43,470
The total sum of these items being equal to the estimated annual income from stumpage	$163,320

The assessed value as thus determined, or $1,598,000 for the 40,000-acre property, should remain the assessed value for the duration of the plan under which it had been determined. It should not drop with cutting, as is the practice with the present application of the general property tax, because the assessment would be based upon a calculation that provides for the building up of a depletion fund from income designed to keep intact the total investment represented by the timber. The depletion fund as it accumulates should, however, be exempt from taxation until the property is liquidated. This would be effected, in part at least, if the company used the depletion fund to retire such bonded debt as it might have assumed at the time of organization. Beyond the point that this should be possible, or if the company should have no bonded debt, the depletion fund would have to be invested in tax-exempt securities, or specifically exempted from taxation in some other manner.

In applying the principle to properties which were being operated

under plans aiming at sustained yield a simple modification of the formula is all that is required. Growth of timber, when the property is managed under a sound plan, will provide for the maintenance of the forest capital intact, and hence there is no necesssity for setting up a depletion fund. The value of a forest property producing a permanent annual income would be determined for tax purposes by the formula $P = \frac{A}{0.0i + 0.0t}$, in which P is the value to be determined, A is the annual income from stumpage, i is the rate of return allowed on the value P, and t is the rate of taxation to be levied against the value P. In a case such as this a separate value for the land would not be determined since the land would be an integral part of the producing property and would not be released for other uses as cutting progressed.

With an assessment procedure such as this in force the percentage of net income taken by the tax is determined by the relative amounts of the capitalizing and tax rates. In this illustrative case it would be 20 per cent, for the sum of the capitalizing and tax rates is 7.5 per cent and 1.5 per cent is 20 per cent of 7.5 per cent. That this same percentage of net income would be taken by the tax as long as the capitalizing, sinking fund, and tax rates remained unchanged, regardless of the plan of management which might be adopted, is demonstrated in Table I, page 322. In this schedule the assessment of the same forest property has been determined under four different plans of management — two aiming at liquidation and two at sustained yield. It is to be noted that, although the annual income and, therefore, the assessment are different in every case, the tax still takes the same percentage of the estimated net income.

Attempts to devise an administrative framework within which this principle of assessment could operate with the minimum of friction have brought to light various difficulties. Some of these have to do with the legal status of taxation in various states, but wherever state constitutions provide for the assessment of property at its true cash value this method of valuation could apparently be adopted, without constitutional amendment or legislative action, as a reasonable method of determining the cash value of forest properties. Other difficulties arise from the way in which timber owners operate their properties, the necessity for providing for changes in management plans, procedure in cases of transfer of title, and the like.

TABLE I

COMPARISON OF TAX BURDEN UNDER VARIOUS PLANS OF MANAGEMENT

Item	Liquidation		Sustained yield			
	20-year period logging	10-year period logging	20-year cycle		10-year cycle	
			1st cycle	2d cycle	1st cycle	2d cycle
A. Annual income before taxes and allowance for depletion	$ 163,320	$ 402,000	$ 136,650	$ 108,420	$ 169,120	$ 157,750
B. Assessment as determined by discount method with interest at 6% and taxes at 1.5%	1,598,000	2,665,700	1,822,000	1,445,600	2,254,900	2,102,000
C. Annual depletion charge accumulating at 6% required to retire assessed value during period	43,470	202,060	Nil	Nil	Nil	Nil
D. Net income after depletion and before taxes (A—C)	119,850	199,940	136,650	108,420	169,120	157,750
E. Annual tax at 1.5% of assessed value	23,970	39,985	27,330	21,684	33,823	31,530
F. Tax as a percentage of net income (E ÷ D)	20%	20%	20%	20%	20%	20%

I do not propose to deal individually with the various administrative difficulties which have been pointed out by those investigating the possibility of applying the principle, but merely to suggest one further step in its application which should serve to do away with the more serious obstacles which have arisen.

If the system is to operate at all, the assessment must remain the same for the duration of a plan unless basic values change or changes are made in the rates of capitalization, sinking fund, or tax. Basic values should certainly be reviewed as often as once in five years, and it would surely be only equitable to allow an owner to present for approval an alternative plan, should his original plan

not prove suitable to his needs. Furthermore, an owner should not be required to cut annually the exact amount of timber which was the basis of his assessment, but should have some latitude in adjusting his cut to market and operating conditions. When these points are given consideration serious attention must be paid to the possibility of tax evasion. It must be borne in mind that under a liquidating plan the discount principle of assessment levies a lower tax upon the timber property at the commencement of the period of liquidation than would be paid under normal assessment procedure and a higher tax as the period of liquidation draws to a close. In the case of the twenty-year liquidating plan previously referred to the normal tax on the property before operation commenced would be, on fair stumpage appraisal and with a tax rate of 1.5 per cent, $48,996. This would decrease with cutting, under ordinary assessment procedure, at the rate of $2,449.80 per year. Under the discount principle taxes would be $23,970 continuously and would be less than those levied under ordinary assessment procedure for the first eleven years of operation and progressively greater thereafter. It would obviously be possible for the owner to take the benefit of the lower rate of taxation for the first eleven years of operation and then increase his cutting rate so as to complete his operation in another five years. Thus he might avoid paying the tax called for during the last four years of operation originally contemplated under the plan and leave the state with no tax base upon which to levy and no recourse other than litigation if it is to obtain the full amount of taxes called for under the plan originally approved.

To avoid this possibility of tax evasion and to give an owner some latitude in adjusting his cut to market and operating conditions, it is suggested that it would be desirable to "freeze" the assessment under any plan, not only with regard to area (legal description) and time, but also with regard to annual cut. Again referring to the twenty-year liquidating plan previously cited, one may note that the annual tax of $23,970 is predicated upon an annual cut of 25,782 M ft.b.m. (1/20 of 515,640 M ft.b.m.). Therefore, the annual tax amounts to 92.9¢ or, say, 93¢ per M ft.b.m. of annual cut. It would not be feasible merely to levy a tax of this amount on each thousand feet cut as operation proceeded, because it would only be necessary for an operator to present a plan, get a stumpage valuation under it, and then refrain from cutting in order to evade taxes. However, in case

provision is made that the minimum annual tax under the plan would be $23,970, but that an additional tax of 93¢ per M ft.b.m. should be levied on all timber cut in excess of 25,782 M ft.b.m. in any year, then the operator could change his plan and increase his cut at any time without loss of tax revenue to the state. In order to allow for the perfectly reasonable desire of an owner to cut more than his estimated annual production in some years and less in others, it would be equitable to provide further that, no matter what the rate of cutting might be, the total of taxes paid under the plan at completion of liquidation should not exceed the total originally estimated, i.e. 20 × $23,970, or $479,400.

Justification for this method of applying the system is found in the fact that, after all, the system is no more than scientific appraisal of stumpage for taxation purposes. It is, of course, true that the inclusion of this provision would penalize an owner who first obtained assessment under a plan involving a long period of liquidation, or under a sustained-yield plan, and then decided upon liquidation during a shorter period. However, it may be assumed that one of the purposes of offering this method of assessment to timber owners would be to encourage them to submit plans involving long periods of liquidation which would tend gradually to bring about a condition of effective sustained yield for the industry as a whole, and that any provision which would be a deterrent to the abandonment of such plans would be welcome. It is obvious that such a provision would do away with many administrative difficulties involved in the application of the system as it has hitherto been discussed.

University of Michigan

THE RATING OF FOREST-FIRE DANGER

J. ALFRED MITCHELL

FIRE DANGER DEFINED

FIRE danger is defined as the "sum total of the factors which determine whether fires will start, spread, do damage, and whether and to what extent they can be controlled." The degree of danger prevailing serves, therefore, as an indication of the effort required to handle the fire situation effectively.

DEVELOPMENT OF DANGER RATINGS

In the early days of forest protection little conscious thought was given to rating fire danger, since protective effort was necessarily restricted to obviously critical periods. As protection developed, experience and judgment were depended on to determine the need for action. Repeated failure to meet critical situations, due to inexperience or to poor judgment, and a growing demand for more effective protection soon indicated the need for a more dependable method of rating danger.

The first step in this direction was to determine the normal occurrence and seasonal distribution of fires and area burned. But it was soon found that normal fire occurrence was not a safe guide, since some years were much worse than others; and seasonal distribution, though following the same general pattern from year to year, often varied widely. Number of fires and area burned also proved to be unsatisfactory indexes of the danger prevailing, since both are materially affected by chance and the effectiveness of protective effort.

Recognition of the importance of weather as a factor in determining danger next led to an attempt to rate it on the basis of current weather conditions. Various weather elements were used as indicators. All showed more or less correlation with fire danger, but none were entirely reliable. Relative humidity was the most promising and for a time was thought to be the solution of the problem. Experience showed, however, that it could not be depended on to

give a true indication under all conditions. This led to extensive fundamental research into fire behavior and fire and weather relationships.

Immediately the need for a specific scale of values with which weather conditions and other factors could be correlated arose, for without such a standard we were in the position of a man trying to lift himself by his own bootstraps. A partial solution of the difficulty was found in fuel moisture content, inasmuch as investigation showed that the moisture content of forest-fire fuels very largely determines the readiness with which they burn.

This led to the suggestion by S. B. Show that the direct measurement of fuel moisture content might serve to indicate the degree of fire danger prevailing. Attention was therefore directed to devising a practicable method of determining the moisture content of forest-fire fuels in place. Various methods were developed, such as random sampling, periodic weighing, determination of electrical resistance, and the use of duff hygrometers and of standardized wood samples or "fire-hazard indicator sticks," about which more will be said later. It was found, however, that fuel moisture content, though an acceptable index of inflammability, did not tell the whole story. How to sample conditions adequately over any considerable area also presented a problem.

ELEMENTS OF FIRE DANGER

Briefly, fire danger very largely depends on the following factors: character and amount of fuel present, topography, cover conditions, risk or chance of fires starting, facilities for control, hazard or degree of inflammability prevailing, wind velocity, and visibility.

These may be divided into basic factors, which vary from place to place, but tend to remain constant, and variable factors, which change from day to day. Though in rating fire danger we are primarily interested in the variable factors, since they are directly responsible for current danger, basic conditions must be taken into consideration because they affect the actual degree of danger resulting.

BASIC CONDITIONS IN THE LAKE STATES

In the Lake States the primary forest-fire fuels are grass, leaf litter, herbaceous vegetation, brush, and young second growth.

While it is true that slash, peat, and crown fires are common, fires for the most part start in grass or leaf litter and are largely confined to the fuel types named.

Topography is a minor consideration, since most of the area in need of protection is flat or only moderately broken, and slope, aspect, and elevation do not play the part in determining fire danger that they do in more rugged country. More important is the matter of water levels, because under normal conditions lakes, streams, and swamps form barriers to the spread of fires. When, however, water levels are lowered by prolonged drought or drainage, swamps constitute one of our worst fire hazards.

The importance of cover conditions will be appreciated when it is realized that, on the average, in Michigan 51.8 per cent of the area burned is nontimbered, 47.3 per cent is classed as second growth, and only 0.9 per cent as merchantable timber. On the basis of area protected, the risk of burning (percentage burned over) is 0.04 per cent in the case of merchantable timber; 0.64 per cent for second growth; and 1.74 per cent for nonforest land. In other words, the chance or risk of nontimbered areas burning is forty-three times that of merchantable timber or nearly three times that of second growth. The importance of this is emphasized by the fact that the bulk of the area under protection has been cut over and is now either nontimbered or in second growth.

Another important consideration is that in the Lake States region fire danger is normally intermittent and confined to relatively short periods between rains.

Risk of fires starting and facilities for control, though important elements in an appraisal of danger, need not be considered here.

HAZARD OR INFLAMMABILITY

As pointed out, the inflammability of forest-fire fuels is largely determined by their moisture content. At moisture contents above 25 per cent most fuels are noninflammable, that is to say, they will not burn under normal conditions. Below 25 per cent they become increasingly inflammable.

Thoroughly saturated forest-fire fuels may contain as much as three times their dry weight of water; air-dry fuels, as little as 2 or 3 per cent. In the absence of free moisture wet fuels tend to dry out until their moisture content is in equilibrium with that of the air.

At 100 per cent relative humidity the moisture content of forest-fire fuels in equilibrium with the air is only about 30 to 40 per cent. This explains why wet fuels dry out even though the humidity remains high; also why high humidity alone renders air-dry fuels only slightly noninflammable. Below 30 per cent the moisture content of forest-fire fuels tends to remain in equilibrium with relative humidity, increasing if the humidity rises and decreasing if it falls.

The chief source of fuel moisture is precipitation; hence the occurrence and the amount of precipitation have an important bearing on fire danger. As a rule, 0.2 of an inch of rain is sufficient to extinguish going fires and to render forest-fire fuels in general noninflammable. Less than 0.2 of an inch of rain affords only partial or temporary relief. On the other hand, rains of more than half an inch do not prolong the period of noninflammability of light fuels appreciably, although they tend to reduce the fire danger by increasing soil moisture and raising water levels.

The manner in which rain falls is also significant. Light rains of considerable duration or occurring at frequent intervals often are more effective than is the same amount of precipitation confined to a short period, since much of the latter runs off or soaks into the ground before the fuels can absorb it.

The rate and the extent of drying out of forest-fire fuels depends on several factors, chief among which are: the character of the fuels; the degree to which they are shaded or protected from sun or wind; and current weather conditions.

Studies at Roscommon show that, on the average, light fuels in the open dry out to the point of inflammability within twenty-four hours of the time rain ceases, but that three days are normally required after effective rains for the top inch of litter to become air-dry. Under a cover of jack pine, however, a period of from two to three days is required for litter to become inflammable and from four to five days or longer for it to reach equilibrium with the air. Heavy fuels and fuels under hardwood cover dry out still more slowly.

Another point to be noted in this connection is that fuels in the forest seldom if ever become as dry as they do in the open, the extent of drying depending on the character and the density of the forest canopy. The effectiveness of forest cover in retarding and limiting drying drops rapidly, however, with a decrease in crown density, and is negligible in open stands.

DETERMINATION OF HAZARD OR INFLAMMABILITY

If forest-fire fuels were uniform and were uniformly distributed and exposed, the determination of fire hazard by the direct measurement of fuel moisture content would be a comparatively simple matter. Since they are not uniform and are anything but uniformly distributed and exposed, the best that can be done by the direct measurement of fuel moisture is to determine the inflammability of typical fuels under specific exposures.

The moisture content of very light or flash fuels, such as tree moss and dead grass, can be approximated from relative humidity, because they tend to remain in equilibrium with air moisture. Heavier fuels, however, respond more slowly, and hence call for other methods of moisture determination. The simplest means of determining the moisture content of moderately light fuel, such as duff and leaf litter, is the duff hygrometer; of heavier fuels, such as dead branches, slash, etc., hazard indicator sticks or standardized wood samples of various sizes and known dry weight. Still heavier fuels, such as logs and snags, must be actually sampled or their moisture content determined by means of electrical or other devices such as are used with lumber.

Fire danger begins when light or flash fuels become inflammable, and increases as the heavier fuels, wooded areas, and swamps dry out. Light fuels and exposed areas, however, dry out rapidly and reach maximum inflammability in a comparatively short time, whereas heavy fuels, wooded areas, and swamps take much longer. Therefore no one type of fuel or single exposure will give more than an indication of the hazard prevailing over any considerable area. A variety of fuels and exposures must be sampled to get a complete picture. The practical limitations to rating hazard by the direct determination of fuel moisture are therefore obvious. Where this method is used measurements are usually limited to more or less fully exposed litter and to wood samples corresponding to slash or to branch wood; in other words, to the fuels and exposures in which fires most commonly start and spread. This serves to indicate when fires of consequence are likely to start and, for the fuels and exposure in question, the degree of hazard prevailing. It fails, however, to indicate the condition of heavier fuels and more protected areas.

The alternative to depending on a necessarily limited number of

direct fuel-moisture measurements for an index of hazard is to determine experimentally the combined effect of the various weather factors on fuel-moisture content and to use weather conditions as an index. Simple and multiple correlations of various weather factors with fuel moisture, both in the open and under forest cover, indicate that wet-bulb depression is the best single index of litter moisture, but that a combination of amount of precipitation, days since rain, minimum relative humidity, and maximum temperature give the highest correlation. On this basis tables have been worked out that indicate the hazard normally prevailing under any probable combination of these factors. This method of hazard determination also has its limitations, but since weather conditions are readily determined and are uniform over a considerable area it has compensating advantages.

WIND VELOCITY AND VISIBILITY

The hazard prevailing having been determined, the effect of current wind velocity and visibility remain to be taken into consideration in arriving at the degree of fire danger prevailing, for wind velocity largely determines rate of spread, and visibility the promptness of discovery — and hence the size of fires when reached.

The extent to which wind velocity affects fire danger has not as yet been precisely determined, nor has a wholly satisfactory way of measuring and rating visibility been achieved. Progress has been made, however, in both these directions, and the influence of these factors can be approximated.

RATING FIRE DANGER

The final step in rating fire danger is to coördinate the factors discussed in such a way that their combined effect can be expressed in units indicative of fire danger. For this purpose an arbitrary scale of danger values has been adopted, based on the intensity of protective effort called for. For convenience in averaging results they have been numbered from 1 to 7. They are defined as follows:

1. *None.* — Fires will not start from a match or spread beyond the heat of a campfire or burning brush pile, though fires in peat and in rotten logs and snags will continue to smolder.

No men needed specifically on fire control except to mop up fires that may be smoldering.

2. *Very low.* — Fires will start from an open flame and from untrenched camp and brush fires, but spread slowly and tend to go out of themselves.

Man lookouts covering areas of special danger, such as slash areas, areas where land-clearing operations are in progress, intensively used recreation areas, etc.

3. *Low.* — Fires will start from a lighted match and will spread (rapidly in dead grass, more slowly in heavier fuels) until extinguished.

Man primary lookouts and keep regular protection force within call.

4. *Moderate.* — Fires start readily from a match, burn briskly, and tend to spread rapidly as they increase in size. Peat fires tend to develop into surface fires at the higher wind velocities.

Man secondary lookouts when visibility is low. Hold regular protection force for immediate action on fires as reported. Keep secondary force within call.

5. *High.* — Fires start readily from a match or glowing cinders, spread rapidly, and tend to crown in young growth.

Hold regular and secondary protection force for immediate action. Notify reserve force to be ready on call.

6. *Very high.* — Fires will start from a cigarette butt or sparks, spread rapidly, and tend to crown generally. Spot fires common.

Man all emergency stations. Mobilize entire protection force for immediate action, provide additional overhead if conditions threaten to remain bad, and call for volunteers or supplemental outside help to be ready if needed.

7. *Extreme.* — Explosive conditions. Fires start readily from sparks, burn fiercely, crown generally, and are all but uncontrollable.

Mobilize supplemental overhead and take other action called for in overload plan.

The actual coördination of hazard, wind velocity, and visibility with the scale of danger values adopted is a matter of experience and judgment based on detailed observations extending over several seasons and on an analysis of available fire reports. Though essentially empirical, the results secured have been a vast improvement on individual personal judgment. For convenience, danger meters have been devised by which the various factors considered can be correlated mechanically and their combined effect in terms

of danger determined. The use of such a guide not only insures the uniform interpretation of conditions prevailing but enables an inexperienced man to arrive at a sound estimate of danger.

Obviously, the last word in regard to measuring fire danger has not yet been said, and much remains to be learned before all the difficulties can be wholly solved.

No attempt has been made in the present paper to do more than outline the problem, the method of attack, and the progress that has been made. The subject is a complex one, and it is probable that there is no precise solution. If, however, a method of rating fire danger can be devised that will enable forest officers to judge conditions more accurately than in the past, the effort expended in this direction will not have been wasted.

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DIAGNOSING PLANTATION MORTALITY

PAUL O. RUDOLF

THE determination of causes of loss in forest plantations may seem at first sight to be of somewhat academic value. However, such an analysis yields much more important information than the mere knowledge of the proportionate rôle which various factors play in reducing the success of plantations. Just as classifications of human mortality by the medical profession indicate fields where particular dangers lie and where knowledge and technique are deficient, so may studies of plantation mortality give warning of similar weaknesses and point out strategic positions for attacking planting problems.

In most survival examinations of forest plantations some attempts are made to list causes of loss. Often the differentiation is based merely on an ocular estimate. At other times a conscientious effort is put forth to classify causes of loss for each nonsurviving tree. However, because of the great variation in conditions encountered throughout any broad region and the fact that men with comparatively little planting experience commonly do the examining, these classifications have frequently been of somewhat general value only and, as a matter of fact, have been put to little use.

SOME PAST DIAGNOSES

In his study of plantations throughout the northern Lake States conducted in 1924 J. Kittredge [1] classified the causes of loss in this region, in order of importance, as follows: fire, drought, heat, freezing, animals, insects, fungi, poor stock and planting, and competition. Such a classification is of value from a broad regional standpoint, but for individual planting operations more detailed data particularly applicable to the locality in question are necessary.

As a part of the comprehensive planting experiment conducted by the Lake States Forest Experiment Station on the Huron Na-

[1] "Forest Planting in the Lake States," *U. S. D. A., Department Bulletin 1497.* 1929.

tional Forest, annual plantation examinations have been made since 1932, in each of which causes of mortality have been listed after careful examination in the field.

To understand more clearly the results of these studies which refer particularly to the Huron National Forest, a brief history of planting

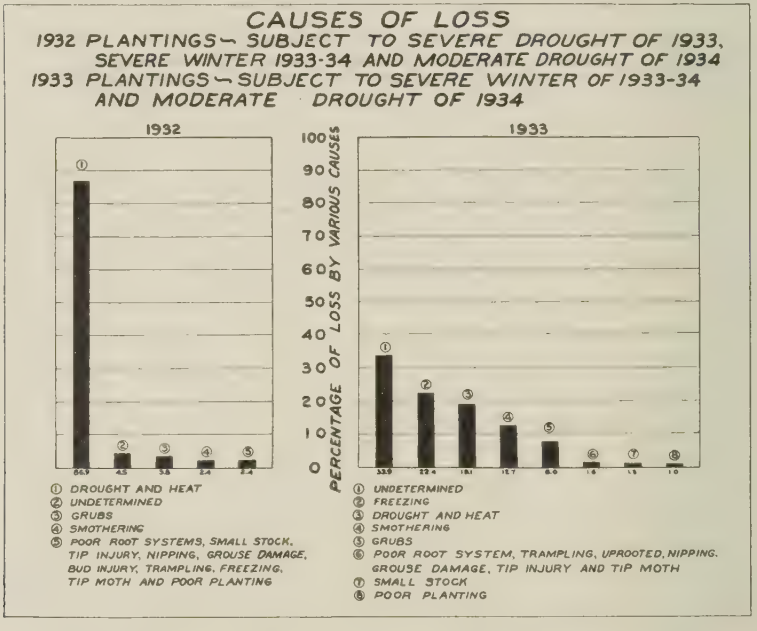

Fig. 1. Comparisons of causes of loss in forest plantations established in 1932 and 1933

in that locality is presented here. This forest, which is in Crawford, Iosco, Ogemaw, and Oscoda counties, Michigan, was established in 1909 upon an area, essentially sand plain in character, which had been logged off and repeatedly burned over. Reforestation was established as a major activity early in its existence. Beginning in 1911, forest planting has been carried out annually upon an increasing scale. Large plantations involving 10,000 acres yearly were already being established here before the advent of the emergency programs in 1933. To date something over 100,000 acres have been planted on this forest.

The examinations made on the experimental plantings indicate both a great variation from year to year in the part played by diverse factors of loss and also give some hint as to the comparative resistance to these same factors of several species and classes of stock.

Figure 1 gives an example of the type of mortality data collected. Results for two dry years, differing considerably in precipitation and temperature, are represented. It will be noted that the importance of the various factors of loss shifted markedly in the two years. For the severe drought year 1933, 87 per cent of the mortality is attributable to drought and heat, with several other factors accounting for the balance. For the moderate drought year 1932, on the other hand, no one cause of loss stands out with such prominence.

PRESENT MORTALITY STUDY

In order to secure even more specific data and particularly to obtain some more definite knowledge of the part which root form and development play in such losses and the proportion of loss directly attributable to heat, a special study [2] was conducted in the fall of 1936, after the very severe drought of that year. It was launched at that time so as to take advantage of the abundant clinical material available before disintegration made accurate diagnosis impossible. In fact, conditions were so severe in 1936 that many of the relationships investigated were obscured. Heat and drought were so intense in many places that sturdy, well-planted trees died as well as poor trees.

This study involved excavation and a careful examination of root systems of some 5,200 trees in 26 plantations. Actual cause of loss and kind of cover were tallied, soil pH and colloid content were determined, and the root systems were classified in three categories: properly planted, slightly deformed, and badly deformed. Although all possible information has not yet been extracted from this study, some interesting facts are already evident. Statistical analysis of a number of the data (see Table I) [3] brought out the following facts:

1. The relationship between root form and mortality (determined by Fisher's "Z" test), generally speaking, is not significant. Only one out of ten jack-pine plantations and four out of fifteen

[2] This study has been carried out coöperatively by the Lake States Forest Experiment Station and the Huron National Forest.

[3] Only part of the results of this study is included in this paper.

TABLE I

PARTIAL SUMMARY: RELATIONSHIP OF SOIL ACIDITY, SOIL COLLOIDAL CONTENT, DROUGHT, HEAT, AND ROOT FORM TO PLANTATION SURVIVAL

Norway pine

Plantation number	Stock	Age from seed	Average pH						Average colloid						Number of nonsurviving trees				Mortality relationship of root form		
			Live trees			Dead trees			Live trees			Dead trees									
			2″	12″	18″	2″	12″	18″	2″	12″	18″	2″	12″	18″	Total	Drought	Heat	Other	Highly significant	Significant	None
P-28	2-0	3	5.4	5.6	5.6	5.6	5.4	5.7	10.1	11.5	10.4	10.6	11.5	10.9	153	23	130	..	..	..	+
P-50	2-0	3	5.5	5.5	5.8	5.9	5.8	5.9	9.9	9.6	9.3	9.5	9.6	9.5	117	82	35	..	..	..	+
P-51	2-0	3	5.7	5.9	5.8	5.8	5.8	5.8	9.8	9.5	9.5	10.0	9.4	9.9	144	100	44	..	..	..	+
P-130	2-0	3	5.3	5.4	5.5	5.3	5.4	5.4	8.0	8.4	8.1	9.4	9.1	8.4	129	46	82	1	..	..	+
P-21	2-0	4	5.6	5.6	6.0	5.6	5.9	5.8	7.1	8.1	9.0	7.7	8.6	6.5	183	28	155	..	..	..	+
P-112	2-0	6	5.4	5.5	5.4	5.2	5.5	5.4	8.2	8.6	8.9	8.9	9.1	9.4	100	20	80	..	..	+	..
P-111	2-0	6	5.4	5.4	5.6	5.1	5.3	5.4	8.4	8.3	8.4	7.0	8.4	8.3	121	33	88	1	..	..	+
P 7	2 0	6	5.3	5.6	5.7	5.6	5.7	5.8	9.9	10.8	9.5	10.1	11.1	9.3	64	0	64	..	..	..	+
P-94	2-0	7	5.2	5.3	5.5	5.0	5.4	5.4	7.9	7.5	8.6	7.5	8.5	8.1	40	12	26	2	..	+	..
P 14	2 0	7	5.8	5.7	5.8	5.9	5.8	5.8	9.6	9.6	10.8	10.0	9.9	9.9	145	117	28	..	..	..	+
P 12	2 0	8	5.5	5.8	5.7	5.8	5.8	5.7	10.5	10.3	10.4	10.3	10.6	9.9	142	98	44	..	..	+	..
P-92	2-0	8	5.0	5.2	5.4	4.6	5.2	5.2	8.5	8.8	8.6	8.6	9.4	8.8	76	9	67	..	..	..	+
P-89	2 0	10	4.9	5.2	5.3	5.3	5.3	5.4	8.3	8.8	8.6	9.3	9.1	8.8	31	10	21	..	..	..	+
P 1	2 0	12	5.5	5.6	5.7	5.2	5.6	5.7	10.2	9.8	10.0	10.6	10.0	10.4	124	66	47	..	..	..	+
P 74	2 0	13	4.8	5.6	5.6	4.7	5.6	5.8	9.4	10.4	9.3	9.7	9.9	8.8	17	5	8	4	+	..	..
Total or average		6.6	5.4	5.5	5.6	5.4	5.6	5.6	9.1	9.3	9.3	9.3	9.6	9.1	106	44 (41.5%)	61 (57.5%)	1 (1.0%)	1	3	11

Jack pine

P-42	1-0	2	5.6	5.6	5.9	5.6	5.6	5.9	9.0	10.1	10.0	8.8	10.1	9.8	119	13	106	..	..	..	+
P-43	1-0	2	5.6	5.5	5.9	5.8	5.7	5.9	7.1	9.3	9.8	7.1	8.6	9.4	105	5	100	..	..	..	+
P-33	1-0	2	5.3	5.5	5.8	5.4	5.7	5.9	8.6	9.2	8.6	8.8	10.3	9.4	71	38	33	..	..	..	+
P-29	1-0	2	5.3	5.6	5.7	5.6	5.6	6.0	8.6	10.5	10.1	8.6	10.8	9.4	166	3	163	..	..	..	+
P 131	1 0	2	5.8	5.7	5.9	5.9	5.6	5.7	11.1	10.8	9.6	9.8	9.8	9.3	134	75	58	1	..	..	+
P 17	1 0	3	5.3	5.5	5.6	5.6	5.5	5.6	10.7	12.8	12.4	10.8	11.7	12.2	115	43	72	..	..	..	+
P 23	1 0	3	5.3	5.5	5.8	5.7	5.8	5.9	8.4	10.5	9.6	9.1	8.9	10.3	121	33	86	2	..	+	..
P 20	1-0	3	5.4	5.9	5.9	5.8	5.7	5.6	10.1	10.1	9.8	10.5	10.0	10.1	172	59	113	..	..	..	+
P 18	1 0	3	5.4	5.5	5.6	5.4	5.4	5.5	8.6	8.8	8.1	7.8	9.1	9.1	144	53	91	..	..	..	+
P-25	1-0	3	5.8	5.6	5.8	5.8	5.6	5.8	9.0	9.3	9.9	7.9	9.7	9.6	124	10	114	..	..	..	+
Total or average		2.5	5.5	5.6	5.8	5.7	5.6	5.8	9.1	10.1	9.8	8.9	9.9	9.9	127.1	32.2 (26.1%)	93.6 (73.6%)	0.3 (0.2%)	0	1	9

Norway-pine plantations showed a significant relationship between these factors. This relationship is strengthened, however, when records of trees with roots cramped into a single plane are sorted out of the data (results not given here).

2. Heat played a major rôle in reducing plantation survival during 1936, with drought accounting for most of the rest of the loss. In the ten jack-pine plantations, averaging only two and one-half years in age from seed, heat caused nearly 74 per cent of the mortality, drought 26 per cent, and other factors a negligible amount. For the fifteen Norway-pine plantations which average nearly seven years in age from seed, heat caused nearly 58 per cent of the loss, drought 41 per cent, and other factors 1 per cent. The lower heat loss for Norway pine was apparently due to the greater average age of the trees and the slightly more abundant cover protecting them.

Heat injury was evident in the field by the discolored ring of "cooked" cambium found on the smaller trees, usually within one inch of the soil surface. In a few cases such "dead" trees were found which still had live roots. The heat was not intense enough to bring about girdling of larger trees (over one-half inch in diameter at the root collar), but did cause lesions on the southwesterly sides of many such trees which are still living, as well as on those which finally succumbed to drought. Previous laboratory tests made at the Experiment Station have proved that two-hour exposures to temperatures of 135° F. are lethal for 2–2 Norway- and white-pine stock. Thermograph records taken on the Huron National Forest experimental plots during 1936 showed a new maximum temperature of 175° F. at the soil surface in the open and one record of eight and one-half consecutive hours with temperatures above 130° F. This definitely indicates that the possibilities of tremendous heat damage were present. Soil moisture samples taken throughout the year also showed that there was sufficient moisture deficiency to bring about death in several localities.

3. Neither soil pH nor colloidal content, as determined with the testing kit used on the national forests, exhibits significant correlation with survival. Samples taken from holes which were left after excavating an equal number of dead and live trees were tested and gave only slightly different average values for dead and live trees for both Norway and jack pine. When Fisher's "t" test was used, these differences were shown to be insignificant.

4. On the average, the trees which died during 1936 were smaller and had less vigorous root development than those which lived (see Plate I). Physical measurement of root extent and shoot length and scale drawing of the root systems made in the field clarify this statement.

SOME PRACTICAL CONCLUSIONS

Although it has been impossible to present the complete analysis of the special mortality study here, the facts which have been brought out point to certain practical conclusions. The greater tendency of smaller trees, especially those with deficient root systems, to die indicates the use of larger, better-developed planting stock to improve survival. The large part of mortality caused by heat indicates several points: (1) use of larger stock, (2) curtailment of planting in large openings, and (3) the use of protective cover, either natural or artificial, to reduce surface soil temperatures. Under conditions represented by the Huron National Forest, such slight differences as there are in soil pH and colloidal content may be disregarded so far as any effects on survival are concerned.

Forest Service, Department of Agriculture
Lake States Forest Experiment Station
University Farm, St. Paul, Minnesota

FIG. 1. Three groups of living and dead trees excavated in plantation P–51, planted in fall of 1935 with 2–0 Norway pine

FIG. 2. Two groups of living and dead trees excavated in plantation P–20, planted in fall of 1934 with 1 0 jack pine

AN INTRODUCTION TO THE STUDY OF TIMBER QUALITY IN LAKE STATES HARDWOODS

HENRY G. WHITE

CURRENT interest in forest management, on more than a purely scholastic basis, has brought to attention the need for accurate and selective measures of timber quality and value. Selective or partial logging, particularly, as a practical means of obtaining a sustained yield from the forest, has made foresters think in financial terms rather than in terms of theoretical silvicultural systems. The forest manager, like any other business executive, wants to know the quality and the value of the timber which is the capital of his enterprise, and he wants to know the value of the products of the forest.

So long as clear-cutting methods of exploitation prevail, the board measure and a roughly estimated cull factor serve reasonably well in determining the net merchantable volume of any particular stand of timber. For determining quality and value the mill run of each species serves the purpose. But for the determination of the value of selectively or partially cut timber on the basis either of its current stumpage price or of potential growth no accurate method has been available. Obviously, woods-run values based on clear-cutting cannot fairly be applied to remaining timber, whatever the nature of the partial cutting. If a light selective cutting has been carefully made under strict marking practice, removing only the defective and the overmature trees, the residual timber may very possibly be worth more than average log-run values would indicate. On the other hand, if the "cream" of the timber has been removed, leaving the trees of poorer quality and less valuable species, then a purchaser of the stumpage would be paying too much if he used a log-run price scale.

In the past, studies have been made of variations in logging and milling costs and selling prices according to tree and log size;[1] but

[1] Zon, Raphael, and Garver, R. D., "Selective Logging in the Northern Hardwoods of the Lake States," *U. S. D. A. Tech. Bull.*, No. 164.

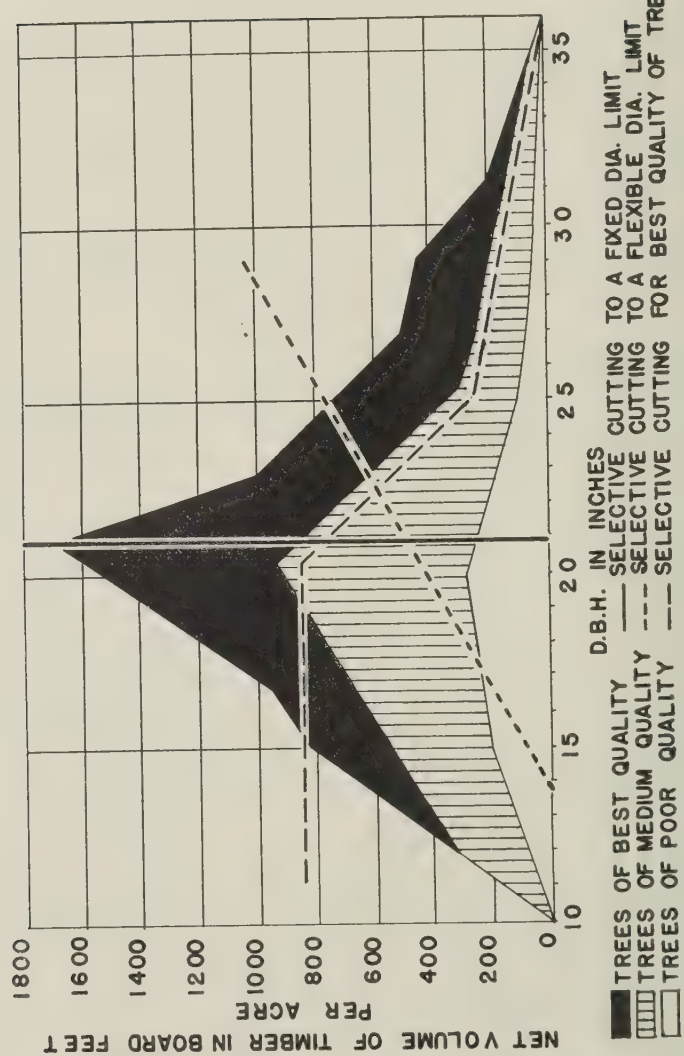

Fig. 1. Selective cuttings in a typical mixed hardwood stand in upper Michigan

because of variations in log quality within each tree and log-diameter class it would be dangerous to apply these results to culled-over or selectively cut timber. Figure 1 will perhaps clarify this situation. It shows a hypothetical distribution of tree quality to diameter classes in a typical northern hardwood stand, the lower white part of the area below the curve representing trees of the poorest quality; the central shaded part, trees of medium quality; and the black upper margin, the trees containing the best quality of logs. (See Pl. I for a picture of a typical stand of hardwood timber in the Upper Peninsula of Michigan.)

If this stand of timber is to be partially cut, the solid black line shows the result of a selective cutting to a fixed diameter limit; that is, the area to the right of this line will be cut and the remainder will be left standing. The dotted line shows a selective cutting to a flexible diameter limit; the dashed line, a cutting which has harvested the cream of the timber. Each cut would remove approximately an equal volume of timber from the stand. But, as compared with the first cutting, the selective cutting to a flexible diameter limit has harvested poor-quality trees in place of the more vigorous growing stock between 21 and 25 inches in diameter. The "creaming" cut, on the other hand, leaves nothing but trees of poorer quality. Obviously, any financial calculations based on these cuttings which do not take cognizance of such variations in quality of primary cut and residual timber will go far wrong.

The need for some means of measuring quality of timber is further witnessed by efforts to calculate growth in selectively logged stands. So far it has been possible to measure acceleration only in gross and net growth. On the basis of stimulated growth a reasonably good case for selective logging has been built up. If it can be demonstrated that selective cutting brings an even larger increment in quality and value of growth, then the arguments for this form of management will be more persuasive. Data of this sort will also serve as a guide in marking for selective cutting.

These ideas are not entirely new. They have been studied for softwood timber in the west for several years. That hardwoods are more variable in quality and have defects which are more difficult to appraise should be no deterrent. In fact, the wide range of values between grades of hardwood lumber makes grading of log quality even more essential.

LOG-GRADING SYSTEM USED ON FOREST SURVEY

To meet the need for some measure of timber quality log specifications were set up for use in connection with the Forest Survey of the Lake States.[2] These specifications describe three log grades. As is common with such specifications, the descriptive distinctions between log grades are based on two very different types of observations: first, on the size and the external appearance of the log, particularly the character and the position of defects (see Pls. II–III); second, on the output of the log, that is, the percentage of the log that will saw out merchantable lumber and the percentage of the lumber output that will grade No. 1 Common or better.

These two sets of specifications are quite different in their application. The first method of description is a matter of observation and can be more easily applied by a comparatively inexperienced forester. The second is a matter of experience and is of less use to an inexperienced cruiser. The percentage of sound wood can be scaled according to standard scaling practice, but the quality of lumber output, No. 1 Common or better, can be only roughly estimated even by an experienced woodsman. Quality of output does, however, serve as a ready check for the experienced grader. The inexperienced cruiser had best adhere rather rigidly to the minimum standards for each log grade as to size and allowable defects.

The exact log-grade specifications used on the Forest Survey are appended to this discussion. In brief, they are as follows:

No. 1 logs must be at least 12 feet long and 12 inches in diameter inside the bark at the small end. One to three standard defects are allowed for rot or other cull, or 10 to 20 per cent deduction from the gross scale, the variation depending on the size of the log. A standard defect is defined as "one sound, bright knot with a maximum diameter of not more than three inches, or its equivalent in damage to the product of the log." No. 1 logs must saw out 60 per cent or more of No. 1 Common or better.

No. 2 logs must generally be at least 10 feet long and 8 inches in diameter inside the bark at the small end. An exception to these size requirements is permitted in a few of the best 8-foot cuts 10 inches in diameter, which, like all longer logs less than 10 inches in

[2] Carried on by the Lake States Forest Experiment Station, University Farm, St. Paul, Minnesota.

diameter, must be surface-clear, straight, and sound. Larger logs are permitted up to three standard defects. As to lumber output, No. 2 logs must cut out 75 per cent sound, of which 30 per cent must be No. 1 Common or better.

No. 3 logs include all other logs suitable for ties, timber, or low-grade lumber. For most species the minimum size requirements are 8-foot length and 8-inch diameter. These logs will generally cut out 50 per cent sound. Average timber in the class will, perhaps, grade 10 per cent No. 1 Common or better, although this amount will vary with the utilization standards on the particular operation.

The application of log-grade specifications is not without pitfalls. There is admitted risk of variation in application. However, this does not invalidate the system; it merely makes careful adherence to specifications essential.

AVERAGE QUALITY OF LAKE STATES HARDWOOD TIMBER AS DETERMINED ON THE FOREST SURVEY

On the Forest Survey of the Upper Peninsula of Michigan sample trees were graded according to these log specifications. The results for sugar maple, yellow birch, basswood, and elm are presented here by diameter and percentage of the net volume (see the graphs, Fig. 2, p. 344). The black part of the graph shows the percentage of the volume which graded No. 1. The shaded area between the lower and the upper curves represents the portion of the volume which graded No. 2 logs. The area between the upper curve and 100 per cent (unshaded) is the volume of No. 3 logs — the logs of poorest quality and lowest value.

These curves bring out the variation in percentage of log grades with size and with age of tree. For sugar maple the maximum in log quality is reached at about 26 inches diameter breast high, and from that point onward the quality of the timber decreases. For yellow birch, basswood, and elm the general trends are similar, although, of course, with variations.

Weighted by the Forest Survey total inventory volumes (net) sugar maple in upper Michigan is found to average 31 per cent No. 1 logs, 46 per cent No. 2 logs, and 23 per cent No. 3 logs. Yellow birch, basswood, and elm grade somewhat higher in average quality; beech, aspen, red maple, oaks, and other hardwoods average lower in quality (see Fig. 3, p. 344, and Table I).

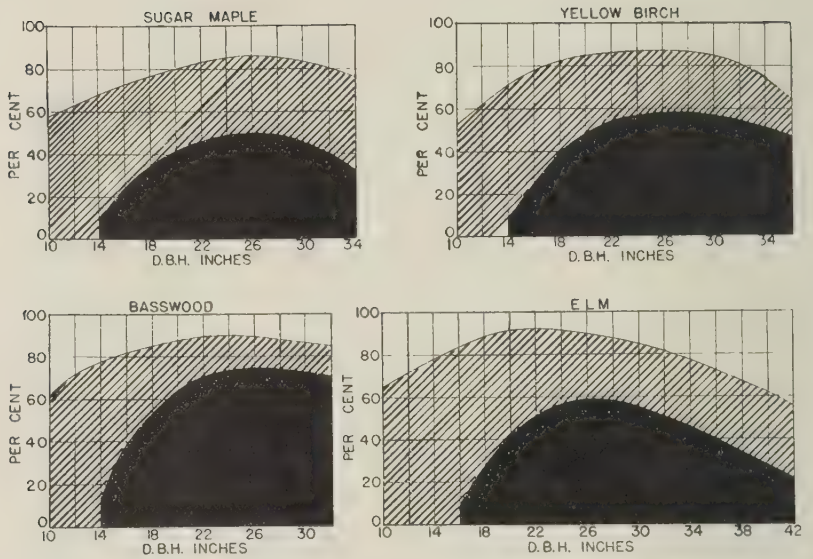

FIG. 2. Quality of hardwood timber in the Upper Peninsula of Michigan. The graphs show the proportion of log grades by D.B.H. classes for principal species

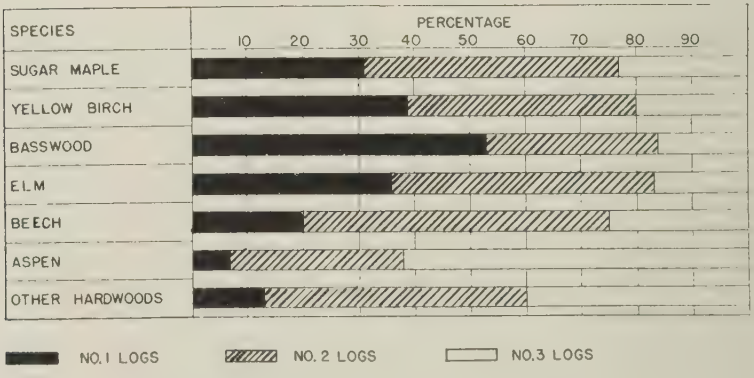

FIG. 3. Proportion of logs in total merchantable volume

TABLE I

Average Quality of Hardwood Timber in Upper Michigan

Species	Percentage of net volume		
	No. 1 logs	No. 2 logs	No. 3 logs
Sugar maple	31	46	23
Yellow birch	39	41	20
Basswood	53	31	16
Elm	36	47	17
Beech	20	55	25
Aspen	7	31	62
Red maple	12	49	39
Oaks	30	36	34
Other hardwoods	13	47	40

The contrast between sugar maple, yellow birch, basswood, and elm checked reasonably well with mill-run averages for larger hardwood mills in Michigan and Wisconsin. This check was made by assuming that No. 1 logs will cut out 60 per cent No. 1 Common or better; No. 2, 30 per cent; and No. 3, 10 per cent.

The contrast in average quality of hardwood timber in upper Michigan with that in Minnesota is very marked (see Fig. 4, p. 346). Naturally the quality of hardwood timber in Minnesota woodlots is considerably poorer than that of the virgin or semivirgin hardwoods of Michigan.

TABLE II

Average Quality of Hardwood Timber in Minnesota

Species	Percentage of net volume		
	No. 1 logs	No. 2 logs	No. 3 logs
Sugar maple	21	43	36
Elm	12	45	43
Basswood	16	54	30
Aspen	5	54	41
Other hardwoods	7	44	49

The figures above carry the story of hardwood log grading about as far as the progress of present work justifies. A need has been felt for a measure of timber quality; log specifications have been set up and

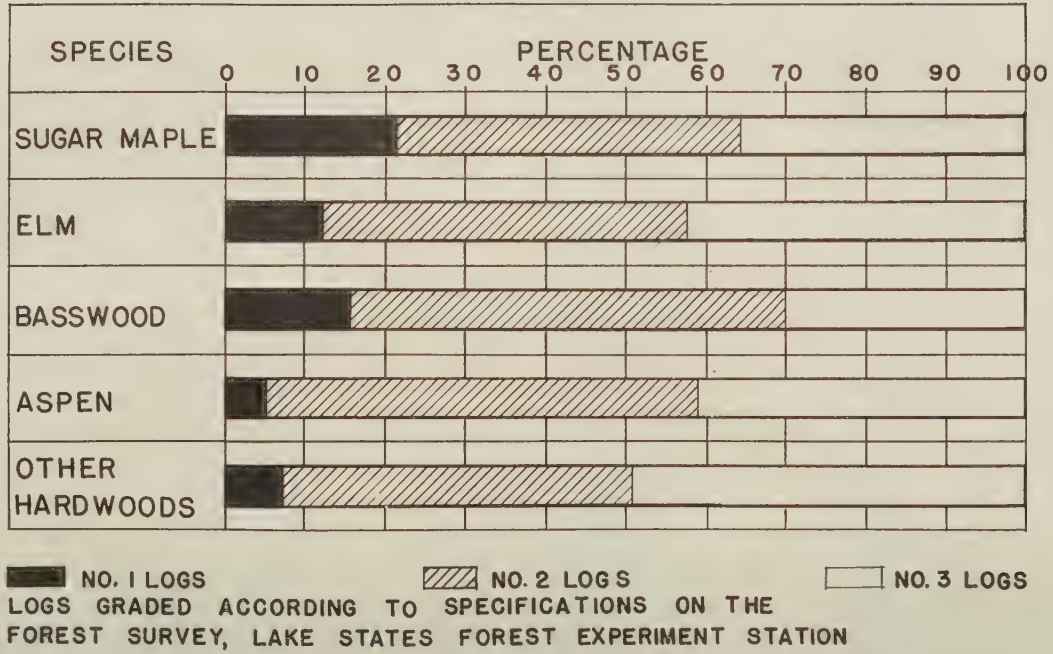

Fig. 4. Quality of hardwood timber in Minnesota. Percentage of log grade in total merchantable volume

put to practical use. The next step is the testing of their correlation with log output and value, and the setting of average output and values for the specifications. These problems are being attacked in a logging and milling study carried on in coöperation with other branches of the Forest Service.[3] The results will be available in the near future. They should throw some clearer light on the matter of variation in log quality and value, and should be of very considerable use in further analysis of the economic aspects of selective logging. With lumber values ranging from over $75 per thousand board feet for Firsts and Seconds hard maple to $17 for No. 3 Common, a No. 1 log of given diameter may produce two or three times the value of lumber that a No. 3 log will produce. These differences in value should no longer be ignored.

Another matter, which there is no space to discuss, is the practical application of log grades. It should be possible to develop a system for grading the standing tree as a unit. If there is sufficient correlation between tree quality and log quality a table of tree output and values can be developed. Such a table would be particularly useful on smaller cruising jobs where grading of logs in sample trees is not feasible.

For the present it is hoped that the log grades which are appended to this discussion will find wide enough use to justify further study of their nature and value.

Forest Service, Department of Agriculture
Lake States Forest Experiment Station
St. Paul, Minnesota

APPENDIX

LOG GRADES USED IN FOREST SURVEY OF THE LAKE STATES

(Hardwoods only)

No. 1 logs: 12- to 16-foot logs — 12 inches or more in diameter inside bark at small end. Logs 12 to 14 inches permit one standard defect or equivalent and 10 per cent heart rot; those 14 to 17 inches, two standard defects and 15 per cent heart rot; those 17 inches and over, three standard defects and hollow, rotten, or shaky hearts up to 20 per cent of diameter. Logs of this grade should cut 60 per cent or more of No. 1 Common and better, or should be suitable for veneer logs.

[3] Forest Products Laboratory, Madison, Wisconsin, and Regional Office, U. S. Forest Service, Milwaukee, Wisconsin.

No. 2 logs: 8-foot logs — 10 inches or more in diameter inside bark at small end — no defects. 10- to 16-foot logs — 8 inches and over inside bark at small end. All logs less than 10 inches to be surface-clear, straight, and sound. Those 10 inches and over must be reasonably straight, not more than 3 inches sweep in 16 feet, and must have at least 6 inches of sound wood around any hollow rot or shake. One tight seam not diverging more than 4 inches from end to end is permitted, and up to three standard defects. Should be 75 per cent sound and cut 30 per cent or more No. 1 Common or better.

No. 3 logs: 8- to 16-foot logs — 8 inches or more in diameter inside bark at small end. Should be suitable for the production of ties, timbers, and low-grade lumber suitable for the manufacture of boxes and crates. These logs should correspond closely with the poorest logs now being utilized by good operators in the region concerned. They should be 50 per cent or more sound.

A standard defect is defined as one sound, bright knot with a maximum diameter of not more than 3 inches, or its equivalent in damage to the product of the log.

Note on grading logs: Sugar maple, yellow birch, basswood, elm, and white ash found in this region usually saw out better than they look. On the other hand, red maple, aspen, black ash, beech, and scrub oak usually open up worse than the surface defects would indicate. For these reasons the logs in the first group should be graded up and those in the second should be graded down.

A typical stand of hardwood timber in the Upper Peninsula of Michigan

FIG. 1. Hard maple, butt log, grade No. 1

FIG. 2. Yellow birch, butt log, grade No. 1

FIG. 1. Hard maple, butt log, grade No. 2

FIG. 2. Hard maple, bucked, in the foreground. Contains a cull butt four feet long, a No. 1 log, a No. 2 log, and a cull section in the top (not utilized)

SOME ASPECTS OF THE URBAN GEOGRAPHY OF SYRACUSE

ERIC H. FAIGLE

LOCATION

THE location of Syracuse at an intersection of important east–west and north–south routes has been of great significance in its development. The Iroquois followed these routes in coming to their council fires, which were held near the site of the present city. Along

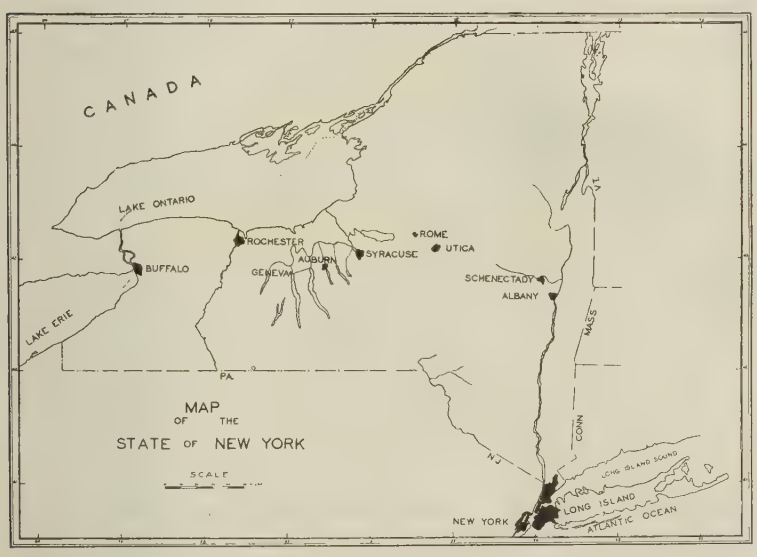

FIG. 1

the old Indian trails came the white man and, at the junction of the two great routes, established the trading post which was later to develop into the city of Syracuse. Since that time transportation by water, rail, and highway has been an important factor in its growth (Figs. 1–2).

Fig. 2

SURFACE CONFIGURATION

This crossing of natural lines of travel can be understood more clearly through a consideration of the situation of Syracuse with reference to the larger surface features of New York State [1] (Fig. 3).

Syracuse lies on the border of the Lake Plains and the Allegheny Plateau, near the western end of the Mohawk Corridor. The northernmost spurs of the Allegheny Plateau are uneven, hilly, and broken, and are characterized by outliers and drumlins. High dividing ridges with deep valleys, in some places several miles wide, extend in a general north–south direction across the plateau. A number of glacial cross channels cut through the ridges. Southwest of Syracuse the valleys are occupied by the Finger Lakes. The position of these lakes and the hilly character of the plateau aided in focusing routes on Syracuse.[2]

[1] Tarr, Ralph S., *Physical Geography of New York State.* London, 1902.

[2] Miller, William J., "Geological History of New York State," *Bull. New York State Museum, No. 168.* Albany, 1913.

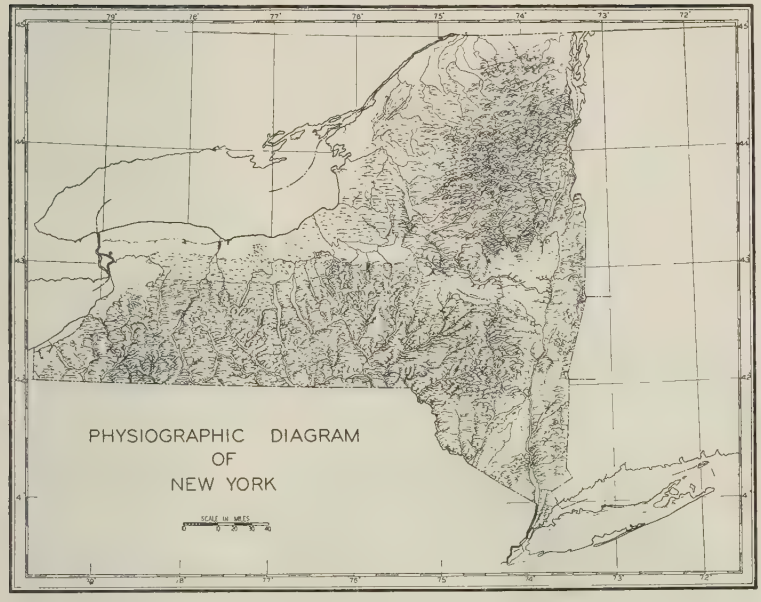

Fig. 3

East of Syracuse the Mohawk Valley, lying between the Adirondack Mountains on the north and the Allegheny Plateau and the Catskill Mountains on the south, forms a great natural gateway which affords an easy means of communication between the regions west of the Appalachian Mountains and the Atlantic seaboard.

EARLY GROWTH

When the occupance of the site began the settlement gave little promise of developing into a thriving community. The site was low, swampy, and uninviting. Its water power was of a very limited amount and unimportant.[3] However, its hub character outweighed these obstacles (Fig. 4, p. 352).

The early roads and, later, the Erie and the Oswego canals passed through the village. With the completion of the Erie Canal in 1825 the growth of the village received remarkable impetus (Fig. 5, p. 353).

Syracuse began to reap the benefits of shipping along the canal

[3] Clark, J. V. H., *Onondaga* (Syracuse, 1849), II: 11.

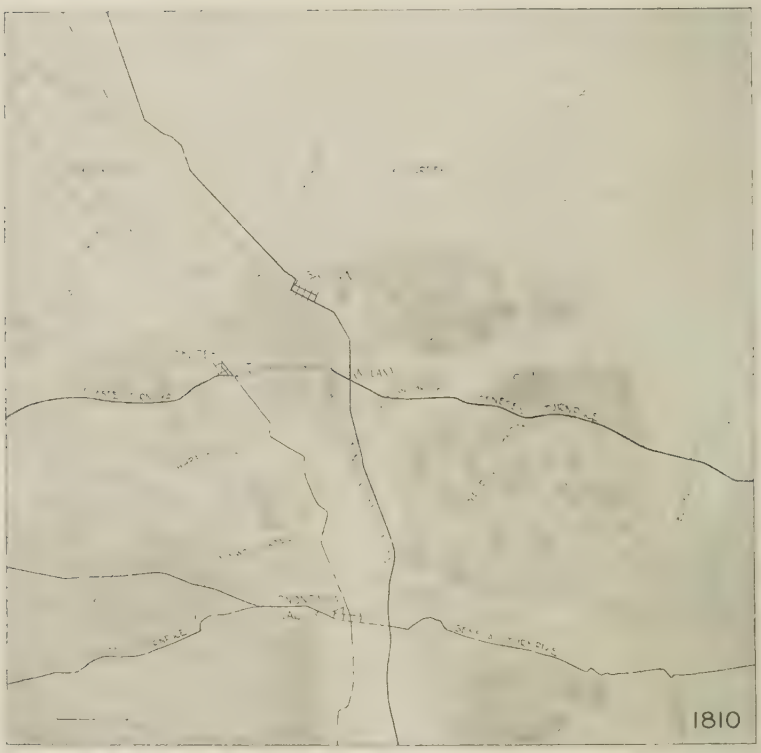

Fig. 4. Syracuse in 1810

and soon drew around its shipping warehouses the population and trade previously shared by places off the canal line. Between the years 1820 and 1830 the population of the town increased 282 per cent (Fig. 6, p. 354).

Cheap transportation made possible the development of the salt industry, a natural resource of great importance.[4]

Central location, good transportation facilities, and the development of the salt industry were the factors which had the greatest effect on the early growth of Syracuse[5] (Figs. 7–9, pp. 355–357).

[4] Hopkins, Thomas C., "The Geology of the Syracuse Quadrangle," *Bull. New York State Museum, No. 171*, pp. 31–34. Albany, 1914.

[5] Bruce, Dwight H., *Onondaga's Centennial*, I : 399–405.

Fig. 5. Syracuse in 1820

FUNDAMENTALS OF THE URBAN SCENE: LANDFORMS

The arrangement of surface features in the vicinity of Syracuse has been fundamental in the development of the present-day urban scene. The center of the city lies at the junction of Onondaga Valley and a glacial cross channel. Much of the low-lying flat land in the city is found either in the valley or in the cross channel, which affords easy routes from one valley to the other. These lowlands have become the industrial and commercial areas.

The flat land of the valley is surrounded by the extensions of the plateau in the form of island land masses topped by drumlins and separated from the plateau by east–west glacial channels. For the

Fig. 6. Syracuse in 1830

most part these higher areas are occupied by residence districts, the University campus, parks, cemeteries, and reservoirs.

Most important to Syracuse is the large channel in the northeastern part of the present city. Through it came the turnpikes, the Erie Canal, and the first railroad. Had it not been for this gap, they would have passed to the north, around the edge of the plateau, and Syracuse would in all probability have grown up on the northern rather than on the southern shore of Onondaga Lake.

In the southeastern part of the city the Delaware, Lackawanna, and Western Railroad and the highways use the easy route of another cross channel to get from Onondaga Valley to Butternut Valley (Fig. 10, p. 358).

Fig. 7. Syracuse in 1850

THE DEVELOPMENT OF THE PRESENT INDUSTRIAL NUCLEUS

Out of the salt industry developed the varied industrial complex of present-day Syracuse. The reservation by the state for salt manufacture of a great tract of land in the northwestern part of the city preserved an area well adapted to industrial uses. When in 1895 the state authorized the sale of the salt lands, the manufacturers took advantage of low prices, convenient location, and proximity to railroad lines to build up a factory section.

Before the salt lands were developed into an industrial nucleus industries were scattered along the lines of the various transportation agencies. This gives the present industrial area an octopus-like

Fig. 8. Syracuse in 1900

appearance, with tentacles extending in several directions (Fig. 11, facing p. 358).

The lands now devoted to industrial uses have an approximate area of 1,725 acres. Of this amount about 533 acres are located within the political limits of the city, and 1,192 are outside and adjacent to the city.[6] Industrial lands, for the most part, have a slope of less than one per cent.

THE PATTERN OF CIRCULATION

The industrial area of Syracuse is closely articulated to the railroads. Eight hundred and seventeen acres, or seven per cent of the

[6] From figures compiled by the City Engineer's Office, Syracuse, New York. Courtesy of Mr. J. Wurn.

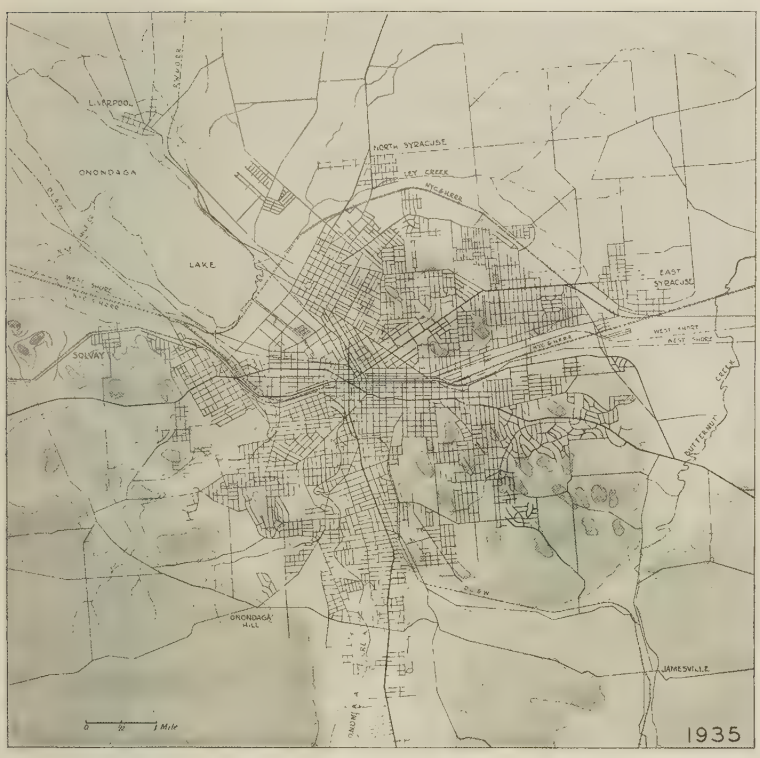

Fig. 9. Syracuse in 1935

total developed area, is in railroad lands, which show an interesting relationship to the surface configuration.[7] These are on the lowlands of the city and, like the industrial lands, have a gradient of less than one per cent.

The present-day street pattern results from the combination of several villages, each of which had its own street pattern. This combination makes rectangular patterns, which gives the appearance of cards lifted up, shuffled, and allowed to fall back again without common orientation. Streets occupy 2,803 acres, or twenty-four per cent of the built-up area.[8]

[7] Bruce, *op. cit.*, p. 6.

[8] *Ibid.*

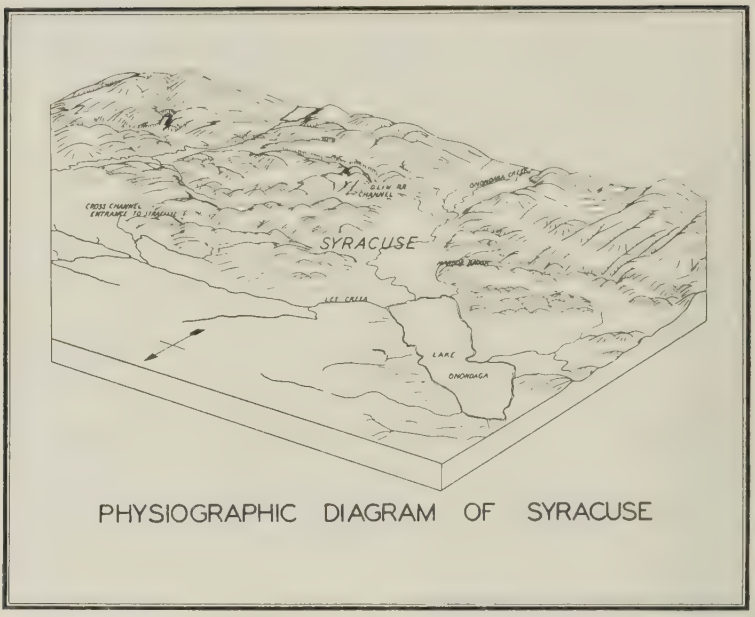

Fig. 10

COMMERCIAL AREAS

The commercial core occupies the flat lands of Onondaga Valley and the Lake Plain. The area contains 444 acres, with a slope between one and three per cent.[9]

Local business districts have grown up in various parts of the city near the residential areas which they serve. They occupy areas which total 539 acres.[10] As a rule, these areas do not have more than six per cent slope. However, they are not restricted to the level lands of Onondaga Valley or to the Lake Plain, as is the commercial core.

PUBLIC AND SEMIPUBLIC AREAS

Areas devoted to public and semipublic property which serves a local function are distributed throughout the city. They occupy 1,832 acres, or fifteen per cent of the total developed area.[11]

[9] Bruce, *op. cit.*, p. 6. [10] *Ibid.* [11] *Ibid.*

FUNCTIONAL AREAS
OF
SYRACUSE

LEGEND

INDUSTRIAL - RAILROAD
COMMERCIAL CORE
LOCAL COMMERCIAL
MULTIPLE RESIDENCES
POOR RESIDENCES
ORDINARY RESIDENCES
SUPERIOR RESIDENCES
CULTURAL CENTERS
PUBLIC - SEMIPUBLIC
VACANT - FARM LAND

SCALE

FIG. 11

RESIDENCE DISTRICTS

Around these several functional nuclei are the residential areas of the city. With the exception of the northwestern part, where Onondaga Lake is located, the residences are arranged concentrically about the functional nuclei and follow the contour features of the locality. They occupy 4,965 acres, or forty-two per cent of the total built-up area.[12]

VACANT LAND

Within the political limits of Syracuse there are in vacant land 4,482 acres, or twenty-seven per cent of the total area of the city [13] (Fig. 11).

CONCLUSION

Since its settlement in 1804 the growth of Syracuse has been steady but not spectacular (Fig. 11). The early roads and canals have been replaced by highways and railroads, and the salt industry has been gradually transformed into a varied pattern of industries, the products of which represent Syracuse in the markets of the world.

The area of the city has been increased by annexation from 250 to 16,418 acres, and the population has grown to 209,326, which makes the city the fourth largest in New York State.

Today Syracuse is a hub city not only because of its central location, but because it is a focal point from which radiate commercial, industrial, cultural, recreational, and administrative functions.

Syracuse University
Syracuse, New York

[12] *Ibid.*

[13] *Ibid.*

AN AMERICAN ADAPTATION OF THE KÖPPEN CLASSIFICATION OF CLIMATES

ALFRED H. MEYER

INCREASING recognition of the geographic value of a quantitative classification of climates, such as the Köppen system, has prompted the writer to formulate a self-sufficient key of this system based on temperature in Fahrenheit degrees and rainfall in inches. Mean temperature and rainfall data of representative stations illustrate a number of the climatic types.[1]

The outline, patterned after the taxonomic keys in botany and zoölogy, shows at a glance the classification principles upon which the Köppen system is based, the types of climate recognized, and the taxonomic position of each climatic type in relation to every other type. It aids in the systematic identification of the several climatic types from station data, and, by substituting formulae, eliminates the necessity of consulting lengthy tables of temperature and rainfall.

From a geographic point of view, however, the identification and classification index serves only as a means to an end. Gradually introduced, part by part, as needed with reference to particular geographic principles or regions, the key has been found a helpful device in simplifying and clarifying the Köppen system. Experience shows that the key in time becomes automatic in readily integrating the elements of climate with the facts and principles of world and regional geography. A graphic form of the key appears in the accompanying figure.

The climatic mosaic is after W. Köppen and Preston E. James. To Professor James, of the Geography Department of the University of Michigan, the author is indebted for helpful criticism.

[1] Data for Miami and Yakutsk from W. G. Kendrew, *The Climates of the Continents*. Oxford University Press, Oxford, 1927.

Data for other stations from H. H. Clayton, *World Weather Records* ("Smithsonian Miscellaneous Collections," Vol. 79). Washington, D.C., 1927.

ANALYTICAL KEY

	Type and subtype	*Symbol*
1. Warmest month below 50 . HIGH LATITUDE OR HIGH ALTITUDE		E
2. Warmest month below 32 . FRIGID		EF
2. Warmest month above 32 . TUNDRA		ET

IVIGTUT, GREENLAND

	J	F	M	A	M	J	J	A	S	O	N	D	Year
T. ...	18.5	18.7	23.5	30.9	40.1	46.6	49.8	47.3	41.0	33.8	26.4	20.7	33.1
Rf. ..	3.3	2.7	3.4	2.4	3.6	3.0	3.3	3.8	6.0	5.9	4.4	3.1	44.9

1. Warmest month above 50 . MIDDLE OR LOW LATITUDE. A, B, C, or D		
2. Annual rainfall less than the following applicable formula indicates: .44 (t − 32),[2] where rainfall of winter 6 months is 70 per cent or more of the total; or .44 (t − 19.5), where rainfall is less unequally distributed; or .44 (t − 7), where rainfall of summer 6 months is 70 per cent or more of the total ... DRY		B
3. Annual rainfall more than one half of that shown in the formulae given ..... *Semiarid steppe*		BS
4. Average temperature below 64.4; warmest month above 64.4 ..... Cool steppe		BSk
5. At least 70 per cent of the rainfall in summer		BSkw
5. At least 70 per cent of the rainfall in winter		BSks(n)[3]

SAN DIEGO, U.S.A.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
T. ...	54.0	54.9	56.5	58.3	60.5	63.5	66.8	68.4	66.9	63.2	59.1	55.6	60.6
Rf. ..	1.8	1.9	1.5	0.6	0.3	0.1	0.1	0.1	0.1	0.4	0.9	1.8	9.6

4. Average temperature below 64.4; warmest month below 64.4 ..... Cold steppe		BSk′
5. At least 70 per cent of the rainfall in summer		BSk′w
4. Average temperature above 64.4 Hot steppe		BSh
5. At least 70 per cent of the rainfall in summer		BShw
5. At least 70 per cent of the rainfall in winter		BShs(n)
3. Annual rainfall less than one half of that shown in the formulae given ..... *True desert*		BW
4. Average temperature below 64.4 Cool desert		BWk
5. At least 70 per cent of the rainfall in summer		BWkw
5. At least 70 per cent of the rainfall in winter		BWks(n)
4. Average temperature below 64.4; warmest month below 64.4 ..... Cold desert		BWk′

[2] The letter "t" stands for "average annual temperature."

[3] The letter "n" is frequently added to BS and BW types to indicate frequent fogs, without quantitative expression.

Santa Cruz, Argentina													*Type and subtype*	*Symbol*
T. . . .	58.8	57.6	54.5	47.9	41.2	35.4	35.1	38.3	43.5	48.8	53.1	56.3	47.5	
Rf. . .	0.6	0.4	0.3	0.6	0.6	0.5	0.7	0.4	0.2	0.4	0.5	0.8	6.0	
													5. At least 70 per cent of the rainfall in summer	BWk′w
													4. Average temperature above 64.4	
													Hot desert	BWh

Phoenix, U.S.A.														
T. . . .	50.4	54.4	60.2	66.9	74.6	84.2	89.6	88.0	81.7	70.0	58.6	51.6	69.2	
Rf. . .	1.0	0.7	0.6	0.4	0.1	0.1	1.3	1.0	0.7	0.5	0.8	0.7	7.9	
													5. At least 70 per cent of the rainfall in summer	BWhw
													5. At least 70 per cent of the rainfall in winter	BWhs(n)
													2. Annual rainfall more than the formula value for the B boundary . . . . . Humid	A, C, or D
													3. Coldest month above 64.4 . *Tropical*	A
													4. Rainfall of driest month at least 2.4	
													Rain forest	Af(i)[4]
													5. Maximum rainfall at the solstices:	
													6. Maximum rainfall in high-sun (summer) period [5] . . .	Afw(i)
													6. Maximum rainfall in low-sun (winter) period	Afs(i)

Sandakan, British North Borneo														
T. . . .	79.8	80.1	81.1	82.3	82.6	81.7	81.8	81.8	81.7	81.5	80.8	80.1	81.3	
Rf. . .	18.4	9.6	8.0	4.1	5.9	7.3	6.5	8.1	9.4	10.0	14.7	17.7	119.7	
													5. Maximum rainfall at the equinoxes:	
													6. Maximum in fall	Afw′(i)
													6. Two maxima, in spring and in fall	Afw″(i)
													4. Rainfall of driest month less than 2.4, but more than the formula value .04 (98.5 − r) [6]	
													Rain forest monsoon	Am(i)
													5. Hottest month before high-sun solstice	Amg(i)
													5. Maximum rainfall at the solstices:	
													6. Maximum rainfall in high-sun period	Amw(i)

Miami, U.S.A.														
T. . . .	65.7	67.8	72.3	74.0	78.5	80.9	82.2	82.4	81.4	77.4	73.2	68.7	75.4	
Rf. . .	3.3	2.5	2.8	3.1	5.9	7.9	7.2	7.3	9.9	9.2	2.4	2.2	63.7	
													6. Maximum rainfall in low-sun period	Ams(i)
													5. Maximum rainfall at the equinoxes:	
													6. Maximum in fall	Amw′(i)
													6. Two maxima, in spring and in fall	Amw″(i)
													4. Rainfall of the driest month less than .04 (98.5 − r)	
													Savanna	Aw, As(i)
													5. Maximum rainfall at the solstices:	
													6. Maximum rainfall in high-sun period	Aw(i)
													7. Maximum temperature before high-sun solstice .	Awg(i)

[4] The letter "i" is added where there is a temperature range of less than 9 degrees between the coldest and the warmest month.

[5] True summers and winters do not occur in the tropics; hence the expressions "high-sun period" and "low-sun period."

[6] The letter "r" stands for "annual rainfall."

Calcutta, India												*Type and subtype*	*Symbol*
T. ...	66.6	71.2	80.2	85.6	86.1	85.1	83.7	83.2	83.2	79.3	73.5	66.5	78.7
Rf. ..	0.4	1.0	1.4	2.2	5.6	11.9	12.7	13.4	10.0	4.9	0.6	0.2	64.3

6. Maximum rainfall in low-sun period ..... As(i)
7. Maximum temperature before high-sun solstice . Asg(i)

5. Maximum rainfall at the equinoxes:
6. Maximum in fall ..... Aw′(i)
7. Maximum temperature before high-sun period . Aw′g(i)
6. Two maxima, in spring and in fall ..... Aw″(i)

Colombo, Ceylon													
T. ...	79.5	80.4	81.8	82.7	82.8	81.6	81.2	81.2	81.2	80.5	80.0	79.5	81.0
Rf. ..	3.2	1.9	4.3	9.7	10.9	7.3	4.4	3.2	4.8	13.4	11.8	5.1	80.0

7. Maximum temperature before high-sun solstice . Aw″g(i)

3. Coldest month between 26.6 and 64.4
Mid-latitude; mild winter C
4. Rainfall of the rainiest month of winter at least three times the rainfall of the driest month of summer; driest month less than 1.2 ..... Summer dry ..... Cs
5. Warmest month above 71.6 . Interior; east coast .... Csa
6. Maximum rainfall in fall ..... Cs′a
5. Warmest month below 71.6 . West coast ..... Csb
6. Hottest month in fall ..... Csbt′(n)

San Francisco, U.S.A.													
T. ...	49.4	51.4	52.8	54.3	55.5	57.2	57.3	57.8	59.9	58.9	55.5	50.6	55.0
Rf. ..	4.8	3.6	3.1	1.6	0.7	0.1	0.0	0.0	0.3	0.9	2.4	4.5	22.0

4. Rainfall of the rainiest month of summer at least ten times the rainfall of the driest month of winter
Winter dry ..... Cw
5. Warmest month above 71.6 ..... Cwa
6. Hottest month before the summer solstice ..... Cwag
5. Warmest month below 71.6 ..... Cwb(i)

Johannesburg, South Africa													
T. ...	66.5	65.4	63.3	59.8	54.4	50.7	50.5	54.3	59.4	62.7	63.5	65.1	59.6
Rf. ..	6.2	5.2	4.4	1.7	0.8	0.1	0.3	0.5	1.0	2.6	5.0	5.4	33.2

4. Rainfall less unequally distributed
Continuously humid ..... Cf
5. Warmest month above 71.6 . Interior; east coast .... Cfa
6. Maximum rainfall in spring ..... Cfax

St. Louis, U.S.A.													
T. ...	31.6	33.7	44.2	55.8	66.2	75.0	79.2	77.3	70.1	58.3	45.4	35.6	56.0
Rf. ..	2.3	2.6	3.5	3.8	4.5	4.6	3.6	3.5	3.2	2.8	2.9	2.5	39.8

5. Warmest month below 71.6, but at least 4 months above 50 ..... West coast ..... Cfb(i)
6. Hottest month before the summer solstice ..... Cfbg(i)
6. Maximum rainfall in winter ..... Cfbs(i)

Sitka, Alaska													*Type and subtype*	*Symbol*
T. ...	31.7	34.1	36.5	41.3	46.6	51.3	54.8	55.5	51.7	45.8	38.2	35.4	43.6	
Rf. ..	7.6	6.5	5.6	5.5	4.1	3.4	4.2	7.1	10.1	12.2	9.5	9.0	84.8	
													5. Warmest month below 71.6; less than 4 months above 50	Cfc(i)
													3. Coldest month below 26.6 . *Mid-latitude; severe winter*	D
													4. Rainfall of the rainiest month of winter at least three times the rainfall of the rainiest month of summer Summer dry	Ds
													5. Warmest month below 71.6	Dsb
													4. Rainfall of the rainiest month of summer at least ten times the rainfall of the driest month of winter Winter dry	Dw
													5. Warmest month above 71.6	Dwa

Mukden, Manchukuo														
T. ...	8.1	14.0	29.7	46.9	60.1	70.5	76.5	74.5	61.3	48.4	29.1	14.0	44.4	
Rf. ..	0.2	0.3	0.7	1.1	2.2	3.4	5.8	5.3	3.3	1.5	0.9	0.2	24.9	
													5. Warmest month below 71.6; but at least 4 months above 50	Dwb
													5. Less than 4 months above 50; coldest month above −36.4	Dwc
													5. Coldest month below −36.4	Dwd

Yakutsk, U.S.S.R.														
T. .	−45.9	−35.1	−10.1	15.8	40.6	59.0	66.2	59.5	42.4	16.2	−20.9	−40.5	12.2	
Rf. .	0.9	0.2	0.4	0.6	1.1	2.1	1.7	2.6	1.2	1.4	0.6	0.9	13.7	
													4. Rainfall less unequally distributed Continuously humid	Df
													5. Warmest month above 71.6	Dfa

Detroit, U.S.A.														
T. ...	24.8	24.7	33.7	46.0	57.8	67.7	72.5	70.2	63.8	52.1	39.3	29.4	48.5	
Rf. ..	2.1	2.2	2.4	2.4	3.3	3.7	3.3	2.8	2.7	2.4	2.4	2.3	32.0	
													5. Warmest month below 71.6; but at least 4 months above 50	Dfb
													5. Less than 4 months above 50; coldest month above −36.4	Dfc

Dawson, Canada														
T. .	−23.1	−11.3	3.8	29.1	46.4	56.7	59.3	54.3	42.4	25.1	0.7	−13.1	22.5	
Rf. .	0.8	0.8	0.5	0.7	0.9	1.3	1.6	1.6	1.7	1.3	1.3	1.1	13.6	
													5. Coldest month below −36.4	Dfd

Example Illustrating Steps in Identification

San Francisco, U.S.A.

T. ...	49.4	51.4	52.8	54.3	55.5	57.2	57.3	57.8	59.9	58.9	55.5	50.6	55.0
Rf. ..	4.8	3.6	3.1	1.6	0.7	0.1	0.0	0.0	0.3	0.9	2.4	4.5	22.0

1. Warmest month above 50. MIDDLE OR LOW LATITUDE
2. Total annual rainfall more than .44 (t − 32)

Humid

3. Coldest month between 26.6 and 64.4 C
4. Rainfall of the rainiest month of winter at least three times that of the driest month of summer; driest month less than 1.2 inches ..... Cs
5. Warmest month below 71.6 ..... Csb
6. Hottest month in fall ..... Csbt'
7. Frequent fogs ..... Csbt'n

Valparaiso University
Valparaiso, Indiana

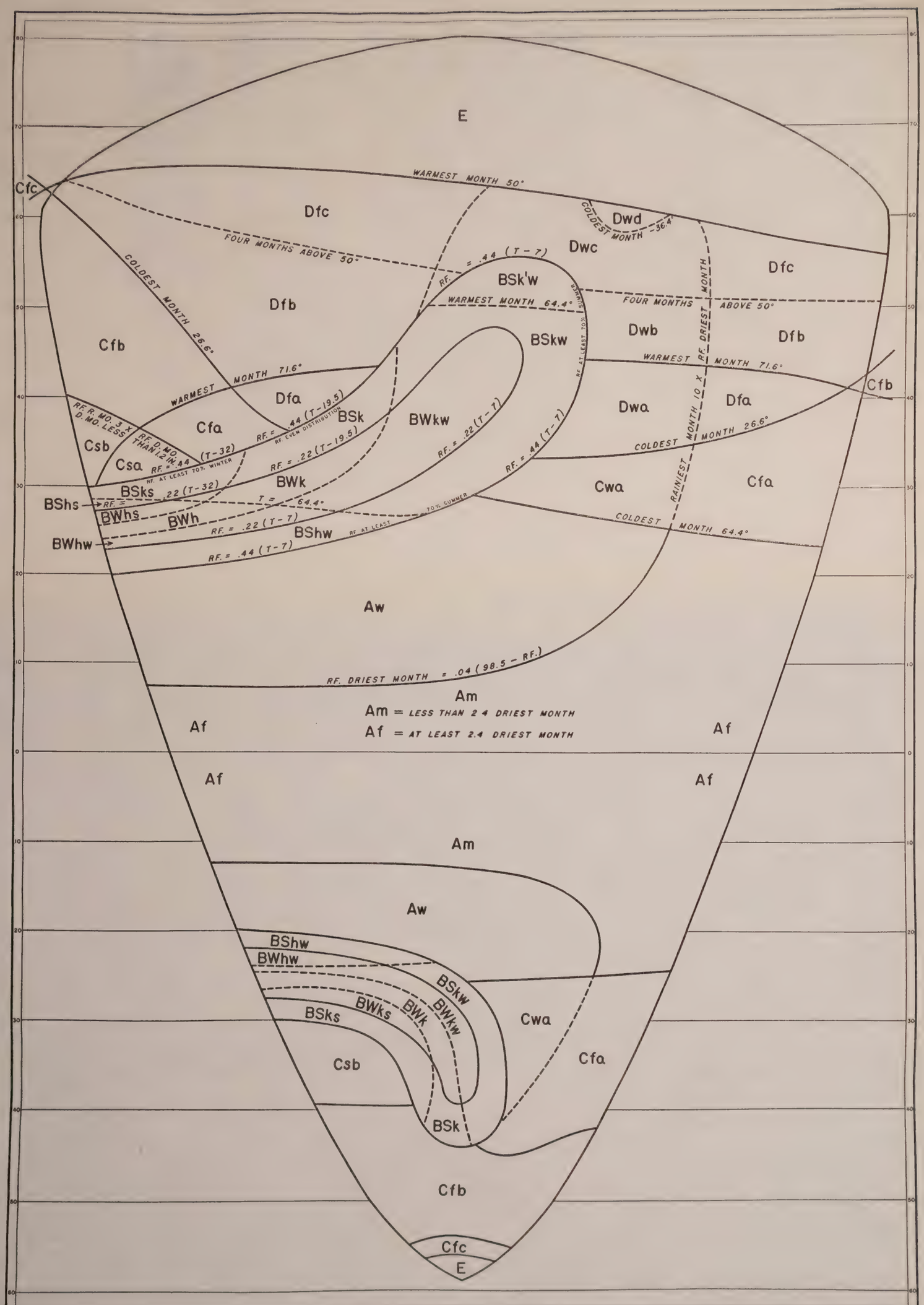

FIG. 1. A self-contained diagrammatic key showing on a hypothetical flat continent the generalized distribution of the chief Köppen types and subtypes of climate, together with the classification criteria and formulae upon which these are based

EXPLANATION

Temperature and rainfall criteria and formulae define and delimit the various climatic types as expressed by letter symbols. For example, in the same latitude the temperature of the warmest or the coldest month on the equatorward side of a given boundary will be above the line value. The line "four months above 50°" delimits on the poleward side the areas having four or more months above 50°. The criterion "rainiest month 10 × RF. driest month" in connection with the Cw and the Dw symbols means that the rainiest month of summer has at least ten times as much rain as the driest month of winter (the "w" indicates the dry season, namely, winter). Desertward stations will have less rainfall than is indicated by the formula values separating the dry from the humid lands. For the meaning of climatic symbols and formulae consult the analytical key.

ABBREVIATIONS: D., driest; In., inches; Mo., month; R., rainiest; Rf., total annual rainfall (inches); T, average annual temperature (Fahrenheit)

BATTLE CREEK: A STUDY IN URBAN GEOGRAPHY

PART I. PRESENT-DAY CITY AND FUNDAMENT

H. THOMPSON STRAW

Introduction

IN THE southernmost part of Michigan there are two lines of cities, each located along what originally were Indian trails and what today are highways radiating from Detroit (Fig. 1). The line farthest south on the map is composed of small market towns, most of them of less than ten thousand population. Here trade is the dominant industry, and what manufacturing exists came late in the history of the city and is still generally of only secondary importance.[1] The second line of cities, immediately north of the first, is composed of somewhat larger urban units, of which Battle Creek is one, and here manufacturing rather than trade is the principal function. Nor did manufacturing come late in the history of these cities. Generally it was the function around which the city was planned.[2]

Perhaps the two most outstanding characteristics of Battle Creek are: first, that it is so well known, which is unusual when its size, less than fifty thousand population, is considered — many cities a great deal larger are much less well known; and second, that its two major industries, the production of cereal preparations and the activities of the sanitarium, are so little related to the surrounding area. Its location in the southern part of the Hay and Dairy Belt [3]

[1] An example of this is Hillsdale. See Straw, H. Thompson, "Hillsdale: An Urban Study of a Small Mid-Western Town," *Journ. Geog.*, 34: 324–334. 1935.

[2] Davis, D. H., "Significant Geographic Problems of the Outwash Plains of Southeastern Michigan," *Journ. Geog.*, 21: 51–53. 1922.

[3] Baker, O. E., "Agricultural Regions of North America. Part V, The Hay and Dairy Belt," *Econ. Geog.*, 4: 44–73. 1928.

places it outside the major areas producing its raw materials, and its proximity to the large urban markets is an advantage shared by many another near-by city. Even more peculiar is the location in this particular city of a health resort. The average American is accustomed to associate health centers with mineral springs, watering places, or seashore and mountain scenery. Battle Creek has none of these. The explanation will have to be found in the evolution of the city rather than in its environs.

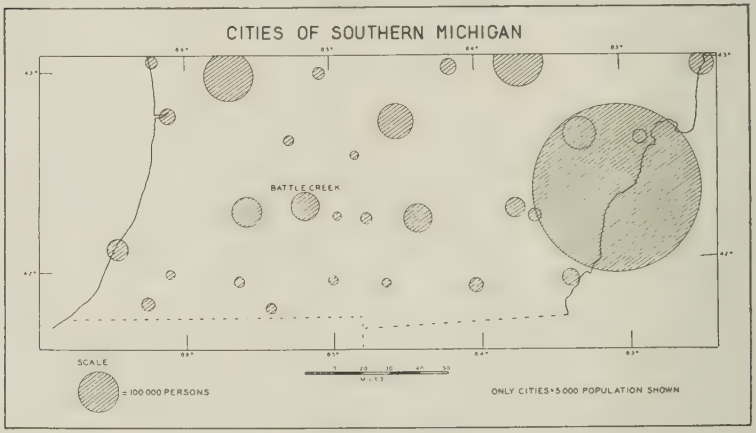

Fig. 1

Present-Day City

Battle Creek occupies a valley about three quarters of a mile wide (Fig. 2).[4] In southern Michigan one is accustomed to a glacial terrain, rough in surface and complex in pattern, and the relatively flat land of the valley bottom, simple in design and bounded by clear-cut limits, serves sharply to differentiate this site from the areas of glacial deposition to the northwest and the southeast.

Two rivers, the Kalamazoo and the Battle Creek, meet here near the center of the city. Both rivers are surprisingly small in relation to the size of the valley, which, though continuing at about the same width, is occupied above the confluence by the smaller of the two streams, the Battle Creek. The Kalamazoo River, on the

[4] Battle Creek Quadrangle, Michigan, U. S. Geol. Surv.

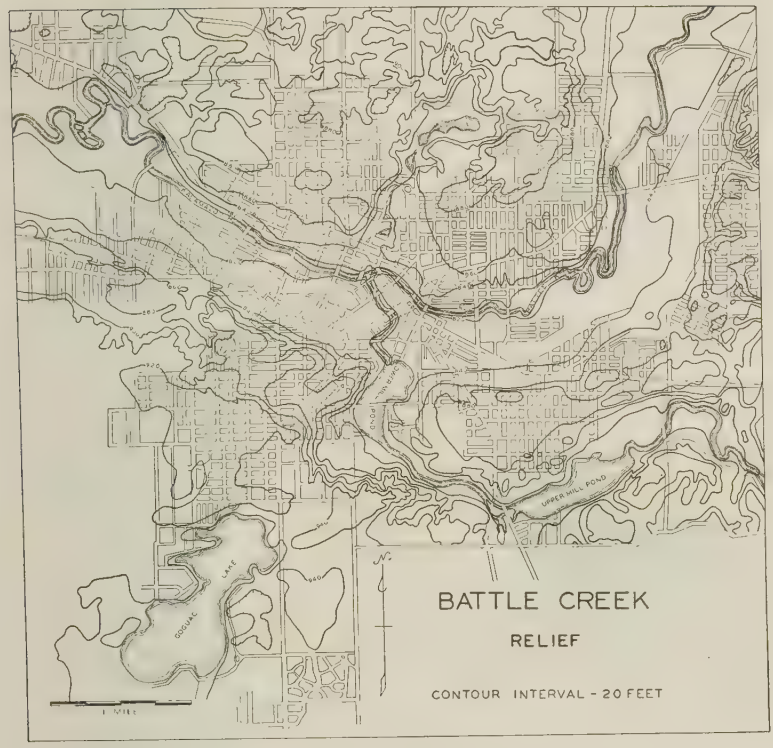

Fig. 2

other hand, above the Upper Mill Pond flows through a valley which is in proportion to the size of the stream. Near the confluence both rivers are confined within the smaller *thalwegs* which they have cut in the larger valley. Upstream the Battle Creek and downstream the Kalamazoo present a different appearance — the flow is less rapid and there are numerous bends and oxbows. Associated with these meanders are large stretches of poorly drained land (Fig. 3).

The valley sides, although in general much more sharply defined than the surrounding glacial area, have many irregularities along them (Fig. 2). The slope which drains Spring Lake, in the northern part of the city, is an excellent example. The lake itself is about a mile from the edge of the valley side, and yet its drainage basin is

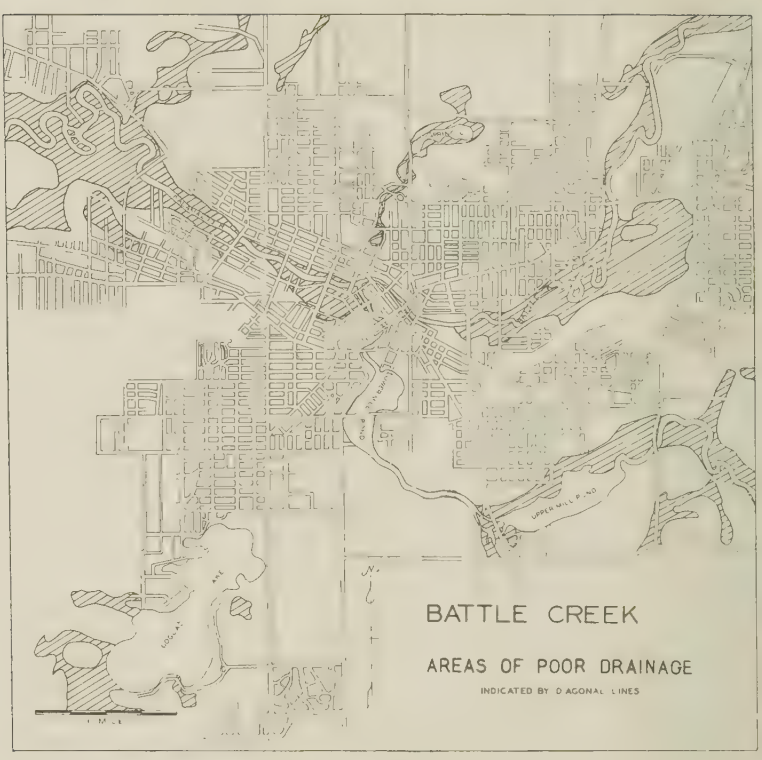

Fig. 3

but little above the general level of the valley floor. The boundaries of the sides vary in sharpness from place to place. In the eastern part of the city they are fairly clear cut, but on the southern slope of the northwestern part of the valley they are very poorly defined.

As the city has outgrown its valley it has expanded upon the higher lands to the north and the south. Here the terrain is distinctly one of glacial origin. Boundaries of any sort are absent, and complexity of surface and of structure is the rule.

STREET PATTERNS

The street pattern of the valley portion of Battle Creek is in harmonious relation to the landforms (Fig. 3). There are five prin-

cipal streets: two which enter from the northwest, one from the northeast, one from the east, and one from the south. These connect Battle Creek with Kalamazoo, Bellevue, Marshall, and Athens, respectively. There are a convergence and a crossing of these routes; the convergence is the result of following the more easily traversed valley floor and avoiding whenever possible the ascent of the valley sides, and the crossing occurs at the better-drained area in the center of the city.

The streets of the higher glacial section are of the rectangular grid pattern characteristic of urban centers laid out in the nineteenth century.[5] Streets which seem to fit into neither of these two groups are mainly those which serve as connecting links between them.

THE ARRANGEMENT OF FUNCTIONAL AREAS

Industry

As one approaches Battle Creek from the higher land one sees in the valley a bristling of smokestacks and water towers, so common to the American manufacturing scene. This picture is most strikingly developed, however, before an impending storm at times when the wind is in the southeast, for then a pall of smoke drifts over the city and seems from a distance to form an unbroken canopy.

The factories are located almost exclusively upon the valley floor (Fig. 4). Here they are in close proximity to the principal roads of the valley and to the railroads. There is a definite division of factories on the basis of size. Those industries close to the commercial core tend to occupy smaller areas, whereas those at some distance generally cover larger units of ground. A scattering of factories, such as one might find in many cities, produce a variety of goods, but the rest may be divided into two distinct groups, the food factories and those making metal products. The food factories are the Battle Creek Food Company, the W. K. Kellogg Company, the Postum Company, and a branch of the Ralston Purina Company (Pl. I, Figs. 1–2). Among the metal-working factories are a few foundries, but these are small. Most of the metal-working industries produce such machinery as bread-wrapping devices, farm appliances, printing presses, and steam pumps. There are also smaller metal products — lawn sprinklers, registers for heating systems, registering machines,

[5] James, P. E., *An Outline of Geography* (Boston: Ginn and Company, 1935), p. 188.

and wire crates and grids. Many of these metal-working factories differ from the food factories in location and in architectural design: their location is usually near the commercial core and the center of the city, and their architectural style is generally less modern (Pl. I, Fig. 3; Pl. II, Fig. 1). Apparently most of them are of earlier origin and existed in the city prior to the growth of the food factories.

Commerce

The commercial core is located near the center of the city, at the chief intersection of routes. There is considerable diversity of form within this core itself (Fig. 5). The principal street and the adjoining areas are occupied by the first-class commercial section (Pl. II, Fig. 2). This section contains most of the apparel, department, furniture, and jewelry stores, and constitutes the shopping area. The second-class commercial district (Pl. II, Fig. 3) extends in a broken ring about the shopping district. It is composed of stores of less pleasing appearance — building-supplies, grocery, and secondhand stores, with small restaurants predominant. The single exception to the generally poor appearance of this area is furnished by the often attractive automobile salesrooms.

There are two types of industry in the commercial core. The first is that, already mentioned, which is usually associated with one or the other of the two rail lines that traverse it. The second consists of a combination of local retail and manufacturing, such as shops selling office supplies and stationery in the front and doing job printing in the rear and bakeries which have small retail shops in the forepart of the buildings. This combination is distributed throughout the second-class commercial area and often at first sight seems to be a part of it (Fig. 5).

Throughout the commercial core there is a scattering of public buildings, and surrounding it is a ring of second- and third-class residence districts. Although not true in all cases, the third-class residence seems to be generally associated with industrial or rail districts.

Outside the commercial core and within the residence district there are also small isolated areas devoted to commerce (Fig. 4). The stores of these areas are small and, generally, are food or drug stores or restaurants, the primary purpose of which is to serve the immediately surrounding residence area. There is a definite concen-

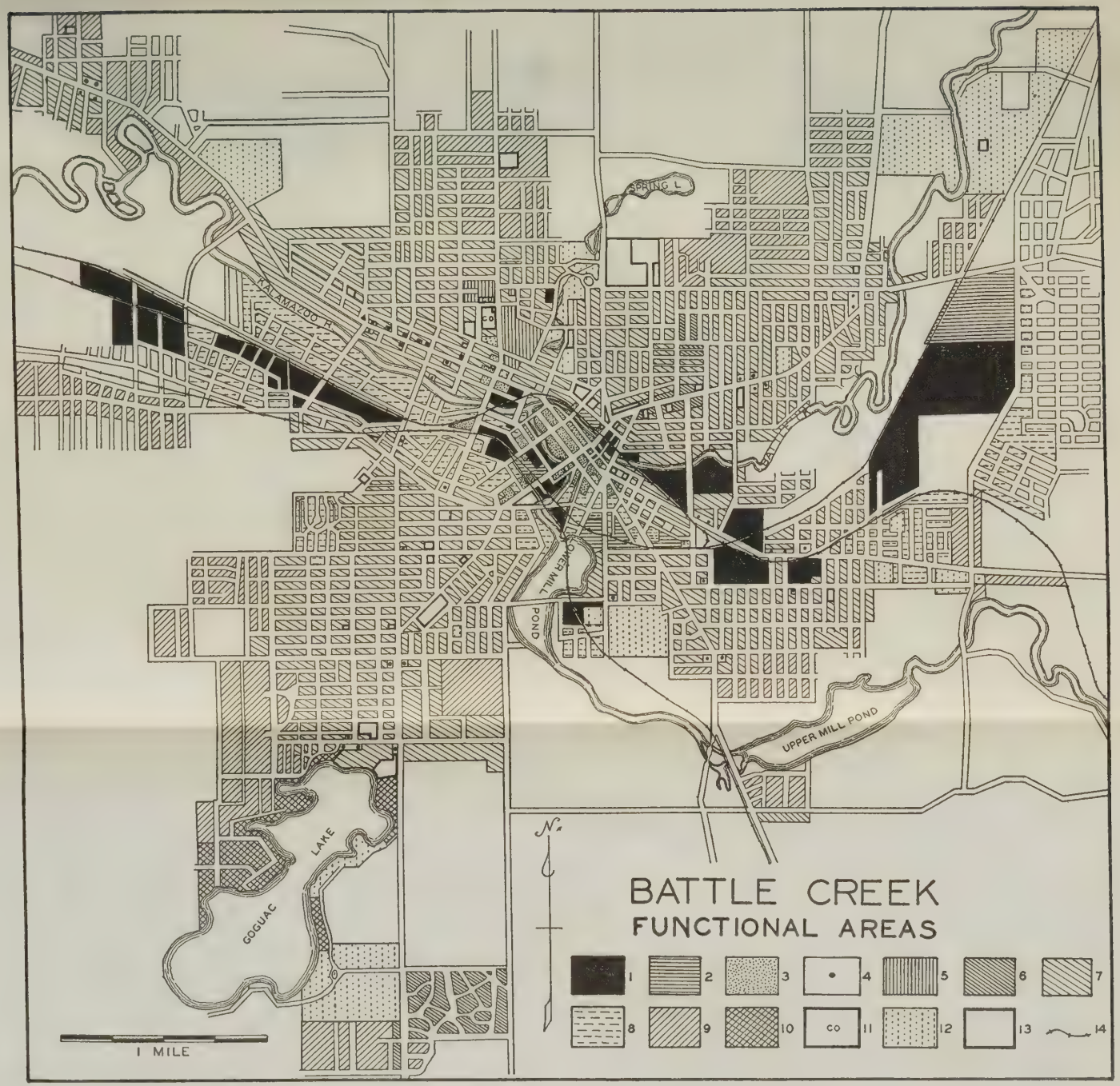

FIG. 4

KEY TO SYMBOLS

1. Industries
2. Area devoted to transportation
3. Commercial core
4. Retail outside area 3
5. Sanitarium
6. First-class residence
7. Second-class residence
8. Third-class residence
9. Suburban residence
10. Summer residence
11. College
12. Parks, cemeteries, and playgrounds
13. Public buildings
14. Railroads

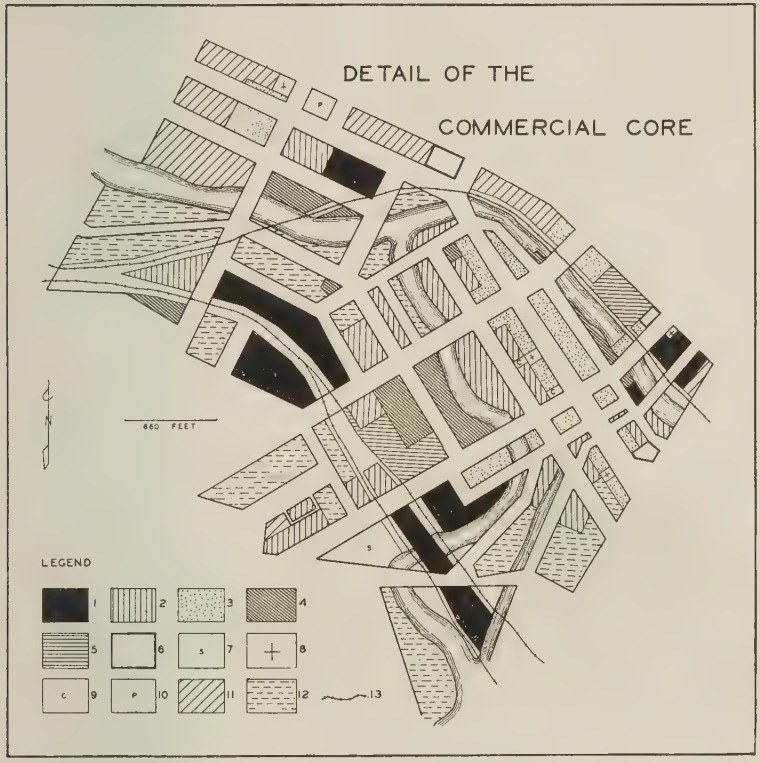

FIG. 5

KEY TO SYMBOLS

1. Industries
2. Second-class commercial core
3. First-class commercial core
4. Local retail and workshop
5. Area devoted to transportation
6. Public buildings
7. Schools
8. Churches
9. City property
10. Parks
11. Second-class residence
12. Third-class residence
13. Railroads

tration of these commercial areas along the main traffic arteries leading from the city. This is particularly true of the road to Verona in the northeastern (Pl. III, Fig. 1) and of the road to Marshall in the eastern parts of the city. Such a location enables the merchant to

be the first to offer services and goods to those arriving and the last to offer them to those leaving.

Along the northern road to Kalamazoo, in the western part of the city, is a broken string of outlying commercial areas. This is a "string-street" [6] development and may very well mark the direction of greatest future expansion of the commercial core itself.

Sanitarium and College

In the western part of the city, upon the land immediately north of the valley, are the sanitarium and the college. The sanitarium is of considerable size (Pl. III, Fig. 2) and rises above the surrounding neighborhood. It is capable of housing some twelve hundred patients. The college, on the other hand, is small, having an enrollment of only about three hundred and fifty students. A few of the buildings are of recent origin (Pl. III, Fig. 3), but the main ones are of a much older style of architecture. Not only are the buildings of the sanitarium and the college in close proximity, but certain ones are for the joint use of both institutions.

Transportation

Intimately connected with the commercial core and the factories is the area devoted to railroad transportation (Fig. 4). Battle Creek is served by both the Grand Trunk Railroad and the Michigan Central Railroad. The area devoted to transportation is unusually large, owing to the location within the city of engine and repair shops of the Grand Trunk Railroad, of which Battle Creek is the divisional center.

The rail lines are laid in the valley section of the city. The Grand Trunk, which enters from the northeast, uses the valley in which the Battle Creek is located. The Michigan Central, which enters from the east, curves northward at the edge of the city, thus avoiding the slight increase of grade which it would have were it to straighten its line (Fig. 2). This same railroad makes another northern bend in the center of the city. West of Battle Creek both railroads occupy the valley. The line which runs south of the city is a branch line and is of relatively small importance.

Besides transportation by rail the city possesses another kind, that by air. The airport is located some distance west of the city. Battle

[6] McKenzie, R. D., *The Metropolitan Community* (New York: McGraw-Hill Book Co., Inc., 1933), pp. 254–256.

Creek is on the air route from Chicago to Detroit, and planes stop regularly for passengers.

Residence Areas

Occupying for the most part the higher land north and south of the valley with its factories and commercial core is the residence district (Fig. 4). Residence in the built-up urban area has been divided into three classes, upon the basis of general appearance. The author's field work was done during the years 1934 and 1935. At that time five to six years of the economic depression had passed. This meant that many homes went unpainted and had unkept yards. In some areas the condition presented no trouble in classification, but in others, where the homes were themselves simple frame buildings of unpretentious styles of architecture, there was great difficulty. Many of these homes, if well taken care of, would be called second-class residence. As they were, however, they had the appearance of being third-class. In the end it was decided to classify them as they would probably be under more normal economic conditions. However, there is no assurance that this aim was always attained.

Third-class residence is generally in close proximity to the factories, the railroads, or the commercial core. That portion associated with the commercial core appears, in part at least, to be decadent (see Pl. IV, Figs. 1–2). Other sections of third-class residence immediately southwest of the commercial core contain a large number of the Negro population. Since there are in Battle Creek no zoning ordinances which segregate the races, the homes of whites and Negroes are intermingled.

First-class residence (Pl. IV, Fig. 3) occupies a very small portion of the residence area. This is explained in part by the location of what will probably develop into first-class residence in the present suburban residence districts (Pl. V, Fig. 1), particularly in the area in the northern part of the city. There is a similar development southeast of Goguac Lake. The first-class residence northeast of the commercial core is the oldest. Although it is still a residence area, that part of it nearest the commercial core is slowly being transformed. The first house at the right in Plate IV, Figure 3, has been turned into an apartment house, the second into a hospital. Farther down the street another is now used as a church. However, the change is slow and not extensive.

Second-class residence occupies most of the residence area (Pl. V, Fig. 2). The suburban residence (area which is less than 50 per cent built up) forms a broken ring about the periphery of the urban residence district.

Scattered throughout these residence areas are public buildings, mostly schools and churches. There are only a few parks, and these are small. In general, the larger parks of the city lie outside the residence area and are of recent development.

One special type of residence, the summer-cottage, occurs on the shore of Goguac Lake. Its extent is small, since much of the lake frontage is given over to a public park and a golf course, and it has contributed little to the growth of the city.

Parks, Subdivisions, and Vacant Land

We have already noted the presence of a few small parks and public grounds scattered throughout the residence areas. Most of these are used either to commemorate some spot of importance in local history or as playgrounds. At the outskirts of the city are larger parks. These appear to be of more recent origin and are designed for recreation.

Surrounding the city, and particularly well developed to the west, are areas of subdivision. Such areas are normal to almost every American city, but here they seem somewhat out of proportion to the size of the city itself. There are approximately three and one-eighth square miles which are practically unused either by the city or for agriculture.

Within the political limits of the city nearly one half of the land is vacant (indicated by white on Fig. 4). In general, two factors explain this: the presence of wasteland associated with the natural drainage of the city and the extension of the city limits to include agricultural land. The wasteland strongly corresponds with the areas of poor drainage (Fig. 3). Although, as can be seen by a comparison with Figure 4, the urban area has in most places pushed toward this undrained section as far as possible, there is much which still remains. The greatest amount of agricultural land within the city limits occurs in the northwestern part. Here it is apparently the result, not of the overambition of the city to acquire territory, but of the natural difficulty of fitting straight lines to the irregular pattern of actual urban use.

Fundament

That certain parts of the general pattern of Battle Creek are closely related to the underlying landforms and drainage has already been noted. Still other parts represent relict forms of earlier occupance, many of which were also related to the terrain in terms of the then usual mode of settlement. Therefore, to arrive at a complete understanding of the city, it is necessary to study the fundament of both its site and its surroundings.

Landforms and drainage

Battle Creek and the area surrounding it lie in that part of the United States affected by the glaciers of the Pleistocene period. The underlying Waverly shale and Marshall sandstone [7] have been so deeply covered by glacial till that they are present at the surface in but few places. Small areas are in evidence where old glacial drainage channels have severely eroded the glacial material (Pl. V, Fig. 3). Otherwise the surface structure is almost entirely a product of glacial deposition.

Although three ice lobes invaded southern Michigan [8] only two, the Lake Michigan and the Saginaw, affected the region about Battle Creek (Fig. 6). The deposits of the third lobe are found farther to the east. Deposition from all lobes occurred during the latter part of the Pleistocene period. A change of climate produced a condition in which the rate of melting exceeded the slow advance of the sheet, and recession took place. Apparently this change from an ice-age climate to something approximating that of today was not a slow, continuous process, but one of fluctuations, for the moraines about Battle Creek exhibit too much relief to have been deposited while the glacier was receding. Rather it would seem that during the short periods of relatively greater cold and precipitation the glacier advanced slightly, and that at the culmination of each short advance a moraine was laid down.[9] This movement and deposition was repeated again and again. The spaces between moraines were generally filled with outwash or, where the retreat of the glacier was more regular, with ground moraine.

[7] Rominger, C., "Geology of the Lower Peninsula," *Geol. Surv. Mich.*, 3, Part I (1873–76) : 69 -70. 1876.

[8] Leverett, Frank, and Taylor, Frank B., "The Pleistocene of Indiana and Michigan," *U. S. Geol. Surv., Mon. 53*, p. 24. 1915. [9] *Ibid.*, pp. 30–32.

The pattern of the various landforms of today is shown on Figure 6. It cannot be assumed that the outlines of the present-day formations more than approximate the original ones. These formations are a part of an area of unusually complex glacial deposits.[10] Much of the outwash plain is not associated with the moraines im-

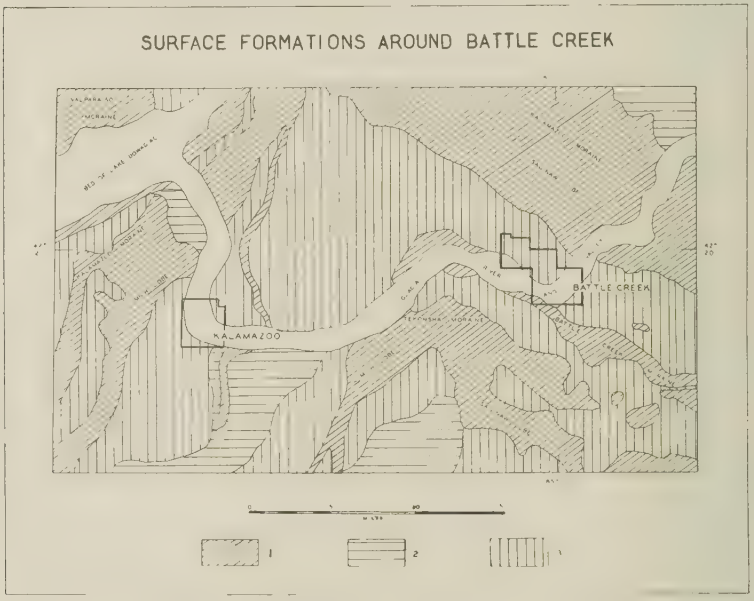

Fig. 6

KEY TO SYMBOLS

1. Moraines 2. Till plains 3. Outwash plains

(After Frank Leverett, "The Country around Camp Custer," *U. S. Geol. Surv.*, Fig. 3. 1918.)

mediately to the north or the west but with those farther away. The glacial streams which deposited the outwash have in many places severely eroded moraines which were formed earlier and which lay at some distance in front of the glacier. At other times the outwash was deposited over the moraines and the till plain, so that many areas designated as outwash on the map may be underlain by earlier and differing deposits.

[10] Davis, *op. cit.*, pp. 50–57.

The first morainic system produced within the area shown on the map was the Tekonsha moraine. It takes the form of an inverted V, with the apex just north of the glacial river valley and northwest of Battle Creek. This moraine, the product of the combined deposition of both the Lake Michigan and the Saginaw lobes, has its reentrant angle about five or six miles west of Battle Creek. The portion of the moraine which lies north of the glacial river valley is a part of the interlobate deposits which were formed between the Lake Michigan and the Saginaw lobes during the later stages of ice withdrawal.[11] In land surface it differs somewhat from the rest of the Tekonsha moraine. Its relief is produced largely by depressions and basins, whereas that of the remainder is caused mostly by ridges and knobs. Large parts of the moraine have been greatly modified by outwash deposition which occurred after the moraine had been laid down by the glacial lobes. One can surmise the earlier existence in many places, especially toward the south, of a more extensive moraine. This surmise seems borne out by the boulder deposits in some of the adjacent outwash areas.

The moraine deposited immediately after the Tekonsha was the Battle Creek. It might perhaps be better to consider the Battle Creek a part of the Tekonsha, since it was at the time of its deposition that the previously mentioned interlobate moraine was laid down. The Battle Creek is, however, a distinct moraine and is separated from the Tekonsha by an outwash plain from one to two miles in width, sloping gently to the south. It is cut off at its southeastern end by the outwash deposited later from the Kalamazoo moraine, and the northwestern end has been eroded by the glacial river, the valley of which is now occupied by the Kalamazoo. At this end the outwash plain is at the same elevation as the moraine and can be differentiated from it only by a less rolling surface and a smaller deposition of boulders. As one travels toward the southeast, however, the difference in elevation of the two deposits becomes more and more apparent. This difference is brought about not by an increase in the elevation of the moraine but by the gentle drop of the general level of the outwash. There is also a gradual change in the type of deposit of the outwash. The larger particles, the gravels and coarse sand, tend to be more abundant in the northern part, whereas finer material is more abundant in the southern.

[11] Leverett and Taylor, *op. cit.*, pp. 152–153.

The moraine deposited next, and separated from the earlier Battle Creek moraine by an outwash plain of considerable size, was the Kalamazoo. The elevation is greatest near the reëntrant angle and decreases as one approaches that part eroded by the glacial stream. The general surface is of the knob-and-basin type. The numerous small lakes near the reëntrant angle are replaced by numerous swamps near the channel.

This old glacial channel occupies for the greater part of its course one of the most extensive outwash plains in southern Michigan. The plain has a very definite southward slope; the elevation at the reentrant angle of the two Kalamazoo moraines is about one thousand feet and drops to about eight hundred feet at the Michigan-Indiana border. The larger gravel particles, as has been mentioned before, are deposited in the north, and the finer materials in the south. From both the slope and the size of particles deposited it would seem that the general trend of glacial drainage on the outwash was southward. Still, the valley occupied by the Kalamazoo River, itself a part of the glacial drainage of this time, travels at right angles to the general trend. Indeed, north of the city of Kalamazoo it turns and continues in a direction exactly opposite to the general trend. Another peculiarity of the valley, as stated before, is the fact that while large parts of it are obviously the result of stream erosion, there are sections of the bluff the outlines of which are so irregular that this general explanation fails to solve the problem of their forms. Examples of this irregularity have been offered within Battle Creek itself.

The only possible solution to this apparent discrepancy seems to be that the old glacial stream followed not a self-made valley but one which, at least in part, had been prepared for it by a series of pits [12] in the outwash. These pits had resulted from the melting of large blocks of ice deposited by the glacier, and they formed the rudiments of a valley which the glacial stream followed and widened. This explains the fact that the direction of the stream differs from the usual one of its time and that its valley sides are so filled with irregularities.

The present Kalamazoo River is a much-underfit stream after reaching the glacial drainage channel and has produced but a narrow, wandering thalweg and a few swamps. It has in scarcely any place modified the valley bluffs of the earlier and larger stream.

[12] Leverett, Frank, "The Country around Camp Custer" (article on reverse side of topographic map "Camp Custer Quadrangle," edition of 1918).

Aside from those which occupy former glacial drainage channels, the streams are for the most part consequent ones which have adapted the direction of their flow to the slope of the glacial deposits. The complexity of the slopes of the deposits is reflected in the frequent changes of direction of the rivers. In detail, one finds lakes which drain in two directions and rivers which trace a tortuous pattern across the terrain. On a traverse of the area one meets the same river in many different and unexpected places. In general, however, the tendency of most rivers is to occupy the outwash and to avoid the till plains and, especially, the moraines.

Associated with the streams are numerous small lakes and swamps, also attesting the early youth of the area.[13] The lakes are of several origins, but those near the city of Battle Creek are most frequently of the pit type, as, for example, Goguac Lake, southwest of the city.[14] Many of the swamps are doubtless the relict forms of earlier lakes. With their heavy growth of grasses they were the popularly called "wet prairies" of pioneer days and the frequent, though often unfortunate, sites of early settlement.

The presence of these numerous swamps and lakes has caused a fairly even regimen of stream flow throughout the area, and thus any possibility of heavy seasonal floods is eliminated. This even regimen was of importance in former days, also, when the use of water power in Battle Creek was more extensive. Late summer ordinarily brought no great diminution of water supply, and thus the period within which manufacturing was possible was not curtailed.[15]

VEGETATION

The vegetation which covered the surrounding country at the time the first settlers came to Battle Creek, although in general determined by climate, in detail is closely related to the various surface forms. The climate of the area places it in the Dfa [16] classification and consequently identifies the natural vegetation as a part of the deciduous broadleaf forest of the middle latitudes. The dominant association is oak-hickory. This has been classified as a xerophytic

[13] Davis, C. M., "The Hydrographic Regions of Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 16 (1931) : 211–215. 1932.

[14] Scott, I. D., "Inland Lakes of Michigan," *Mich. Geol. and Biol. Soil Surv.*, Publ. 30, Geol. Series 25 (Lansing, 1921).

[15] Lane, A. C., "Water Resources of the Lower Peninsula of Michigan," *U. S. Geol. Surv., Water Supply Paper 30*, 1899.

[16] Köppen classification.

phase of the Appalachian Forest.[17] Such a classification seems borne out by the fact that the oak-hickory association changes to a maple-beech association where the upland soil is heavier and of greater clay content,[18] and where, consequently, the amount of moisture available to the tree is greater. The poorly drained mineral soils support a tree growth principally of the elm–ash–silver-maple type.

There are two dry-prairie areas near Battle Creek: one just southwest of the city, called Goguac Prairie, and the other about ten miles southwest, known as Climax Prairie. These areas were covered principally by tall prairie grasses, with a scattering of bur oaks. The explanation of the presence of these prairies in southwestern Michigan seems to lie in a complicated mixture of natural and cultural conditions. The change of climate which caused the retreat of the glacier apparently continued for some centuries after the Pleistocene period and produced a much more xeric condition than that of the present day. It appears that under these favorable circumstances the prairie, now extant in Illinois and westward, reached far north into Michigan.[19] A second change in climate [20] resulted in a condition fostering the present forest cover, and the prairies such as the Goguac and the Climax are existent as relict forms.

These natural conditions favorable to grass growth were supplemented by certain practices of the Indians who inhabited the area. To judge from the Indian remains, aboriginal occupation of many of the prairies was relatively intensive for Indian standards. It was generally the custom to burn the grasses of the prairies in the fall to drive whatever game existed there into the near-by woods, where it could be more easily hunted.[21] This practice encouraged the continuance of grass rather than the growth of trees and augmented the natural conditions which favored its existence. The

[17] Baulig, Henri, *Amérique septentrionale, Géographie universelle*, Tome XIII, edited by P. Vidal de la Blache and L. Gallois (Paris, 1935), colored map: "Les Formes de végétation aux États Unis et dans le sud du Canada," between pages 106 and 107.

[18] Leverett and Taylor, *op. cit.*, p. 180; see also Moon, J. W., Veatch, J. O., Wonser, C. H., and Pasco, R. E., *Soil Survey of Eaton County, Michigan*, Bur. Chem. and Soils, U. S. Dept. Agric., Series 1930, No. 10, p. 3.

[19] Gleason, H. H., "The Vegetational History of the Middle West," *Ann. Assn. Am. Geog.*, 12: 39–85. 1922.

[20] Sears, P. B., "The Archaeology of Environment in Eastern North America," *Am. Anthropol.*, N. S., 34: 612–614. 1932.

[21] Gleason, *op. cit.*, pp. 80–81.

probable importance of the custom seems borne out by the fact that certain uncropped prairies or openings became covered by upland forest after the arrival of the white men.[22]

The first settlers, having learned the use and the advantages of prairie land in Illinois and western Indiana, were attracted to these dry prairies. The land was not so difficult to clear as the forest, could immediately be plowed, was of rich soil with a high humus content, and was especially suitable for wheat, the important pioneer cash crop.[23]

The remaining form of original vegetation is the so-called "wet prairie" or swamp. These soils were unsuitable for pioneer agriculture, but they did provide fields for pasture and hay which did not need an axe to clear them. Many of the early settlements made in the neighborhood of these swamps were unfortunate because the undrained areas fostered the rapid spread of malaria, and the pioneers in such sections usually suffered most from the disease.[24]

Conclusion

Battle Creek has been described as a city with four separate functions: manufacturing, commerce, health, and education, represented respectively by the factories, the commercial core, the sanitarium, and the college. These cores and the other functional areas of the city have been delineated, and their spatial relationships have been indicated. The fundament has also been discussed, and the landforms and the drainage have been shown to be the results of glacial deposition and erosion. The vegetation is correlated in a general way with climate and in detail with surficial conditions. The prairies, forms of an earlier climate, still further complicate the vegetational pattern. The relationships existing between the present-day city and the fundament, such as the distribution of street patterns and the location of transportation areas, have been pointed out.

There still remain, however, many areas the presence of which has not been discussed. These are for the most part forms of an earlier stage of sequent occupance. Just as the presence of the prairies,

[22] Beals, W. L., "Some Changes Now Taking Place in a Forest of Oak Openings," *Fourth Ann. Rep. Mich. Acad. Sci.* (1902), pp. 107–108.

[23] Veatch, J. O., "The Dry Prairies of Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 8 (1927) : 269–278. 1928.

[24] Comstock, O. C., "History of Calhoun County . . .," *Michigan Pioneer Collections*, 2 : 218–220. 1880.

such as the Goguac and the Climax, cannot be explained in terms of present-day climate and surface, so certain urban forms cannot be explained in terms of present-day use. In a later paper the author will trace the sequent occupance of Battle Creek and will show the relationship between it and certain existing urban forms. Likewise the relationship which each of the cores and the city as a whole bear to the surrounding areas which they serve will be described.

State Teachers College
Murfreesboro, Tennessee

FIG. 1. The Kellogg Company

FIG. 2. The Postum Company

FIG. 3. The American Steam Pump Company, at edge of commercial core. Note older style of architecture as compared with that shown in Figures 1–2

FIG. 1. The Oliver Farm Equipment Company. Note older style of architecture as compared with that shown in Plate I, Figures 1–2

FIG. 2. View of shopping district of Battle Creek

FIG. 3. Second-class commercial district. Compare with Figure 2

FIG. 1. Concentration of outlying commercial areas on road to Verona

FIG. 2. Detail of front view of Battle Creek Sanitarium

FIG. 3. View of one of the newer buildings of Battle Creek College

FIG. 1. View of third-class residence near commercial core. From architectural style it was judged to be a decadent area

FIG. 2. View of third-class residence associated with industry in northeastern part of city. Note poor construction of houses as compared with those shown in Figure 1

FIG. 3. View of first-class residence northeast of commercial core

FIG. 1. View of suburban residence in northern part of Battle Creek

FIG. 2. View of second-class residence

FIG. 3. An outcropping of Marshall sandstone in old glacial channel in northeastern part of Battle Creek

PEDOLOGIC EVIDENCE OF CHANGES OF CLIMATE IN MICHIGAN *

JETHRO OTTO VEATCH

THE evidence that the northern part of the United States was covered by a continental ice sheet in the recent geologic past is so convincing that a glacial period is accepted as a fact. Also, a priori, the climate of the land surface exposed by the final retreat of the ice sheet could not conceivably have been the same as the present climate, but must have been much colder. One may speculate whether the change to the warmer condition which exists at present was gradual or whether the curve of change had peaks and hollows of temperature and precipitation, and the scientist may use geologic, ecologic, or pedologic facts to support his theories. For example, ecologists have collected evidence to substantiate a theory that a warmer and drier period existed in the recent past, during which the prairie region extended from Illinois eastward, possibly as far as Pennsylvania.[1]

Some observations which the writer has made, during studies on the genesis of the soils and on the classification of natural land types in Michigan, are here presented with the expectation that they may have value for those who are interested in conjectures regarding the changes in postglacial climate and in theories to account for the existing phenomena of soils, the types and distribution of the original cover of vegetation, and certain topographic features of the state, such as dry valleys and basins. A hypothetical curve of postglacial climate in Michigan is illustrated in Figure 1.

The great number of small prairies in the southwestern part, which may be regarded as relicts of former larger bodies,[2] support the belief that a widespread prairie condition existed in the southern

* Contribution from the Michigan Agricultural Experiment Station, East Lansing, Michigan. Article No. 264 (N.S.).

[1] Transeau, E. N., "The Prairie Peninsula," *Ecology*, 16 (1935): 423–437.

[2] Veatch, J. O., "The Dry Prairies of Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 8 (1927): 269–278. 1928.

section of the state. The profiles of the soils on these "relicts" are markedly different from the dominant forest soil profile of the region and, therefore, may be regarded as abnormal or azonal. The soil difference lies mainly in the darker color and the greater thickness of the surface horizon and the weak development, or absence, of the leached gray or yellowish A_2 horizon of the forest soil profile. These prairie soils, however, are not wiesenboden soils (dark-colored because of wet conditions), since water does not stand on the surface and since the substratum is comparatively dry. Nor are they rendzinas, since the parent material is not sufficiently calcareous. The soils are, in fact, generally strongly acid in reaction to depths

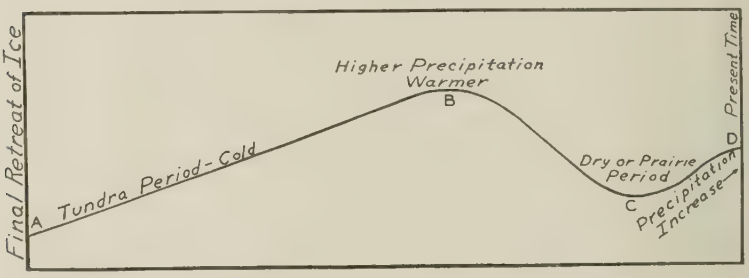

Fig. 1. Hypothetical curve of climatic changes in Michigan

of two to three feet. In addition, the profile generally indicates that the soil is comparatively old, or mature, since a compact clayey B horizon is developed.

These prairie soils very probably were much more widespread in southern Michigan than at present, and the assumption is that their nearly complete extinction by encroachment of forest has been due to a change in climate. The climate during the prairie period may have been warmer and drier than now or it may have been characterized merely by a greater range in temperature or a greater difference in distribution of the total precipitation. Conditions might have been sufficiently dry for the formation of a chernozem soil; but, if so, all observable evidence of such a profile has been obliterated. However, there is evidence farther west in the Prairie Region to support a theory that the dry climate of the High Plains advanced eastward. It is assumed, therefore, that a drier period than the present existed during the formation of the prairies in Michigan.

Fig. 2. Part of Crawford County, Michigan, showing dry valleys

Dry valleys

Plateau highland

Valleys of glacial origin, occupied by streams

The postulation of a dry period may be necessary to explain the existence of dry valleys which are a common feature of the topography in many parts of the state. In numerous places these valleys are dendritic and, therefore, can hardly be explained as constructional features of glacial origin. Illustrations of dry valleys which may represent shallow stream dissection are presented in the sketch map, Figure 2, and in Plate I, Figure 1. The disappearance of the

streams possibly occurred during the dry or prairie period, and the precipitation has not since increased sufficiently to restore them.

It is possible that during this dry stage there was a general shrinkage in the volume of water in the inland lake basins also. There is good evidence that many lakes once stood at higher levels. The argument may be advanced that extinction of lakes and the recession of water levels could have been caused entirely by filling by aquatic vegetation and by natural drainage effected by the downcutting of streams. However, there are numerous basins which do not have stream outlets, but which exhibit good evidence that water levels at one time stood much higher than at present. This evidence consists of thin mucky soil, not underlain by water or by the residue of purely aquatic vegetation; of dry marl deposits of lacustrine origin; and of soil profiles now relatively dry, but which exhibit features characteristic of a wet or water-covered site. There are numerous instances of former lakes which now contain no water at all and in which any peat that may have accumulated has disappeared or has been completely changed to a mineral soil. Some of these dry lake basins, particularly on the outwash plains in Muskegon, Oceana, and Newaygo counties, exist at present as small prairies, having thick dark-colored humous soil. The soil profile could not have formed under the present climate on dry sand parent material, and it is perhaps of significance that species of Opuntia, Andropogon, Artemisia, and Astragalus, and other species common on the prairie land of states to the westward, are growing here.

During this predicated relatively dry and warmer interval most of the old and higher dunes along the shore of Lake Michigan may have been formed, and likewise the features clearly of wind origin on some of the dry sandy plains inland. Also, it is possible to explain by this warmer period the far northward advance of the common northern hardwoods, such as the sugar maple, the beech, and the oaks, and in particular the sparse occurrence of sassafras, as far north as Manistee and Clare counties, and butternut in the upper part of the state. We might also assume that the sugar maple, the beech, and other hardwoods were able to establish themselves on what are now dry sites in the northern part of the state, and that these hardwood species were at one time more widely distributed than at present.

Probably the most cogent pedologic evidence of changes in cli-

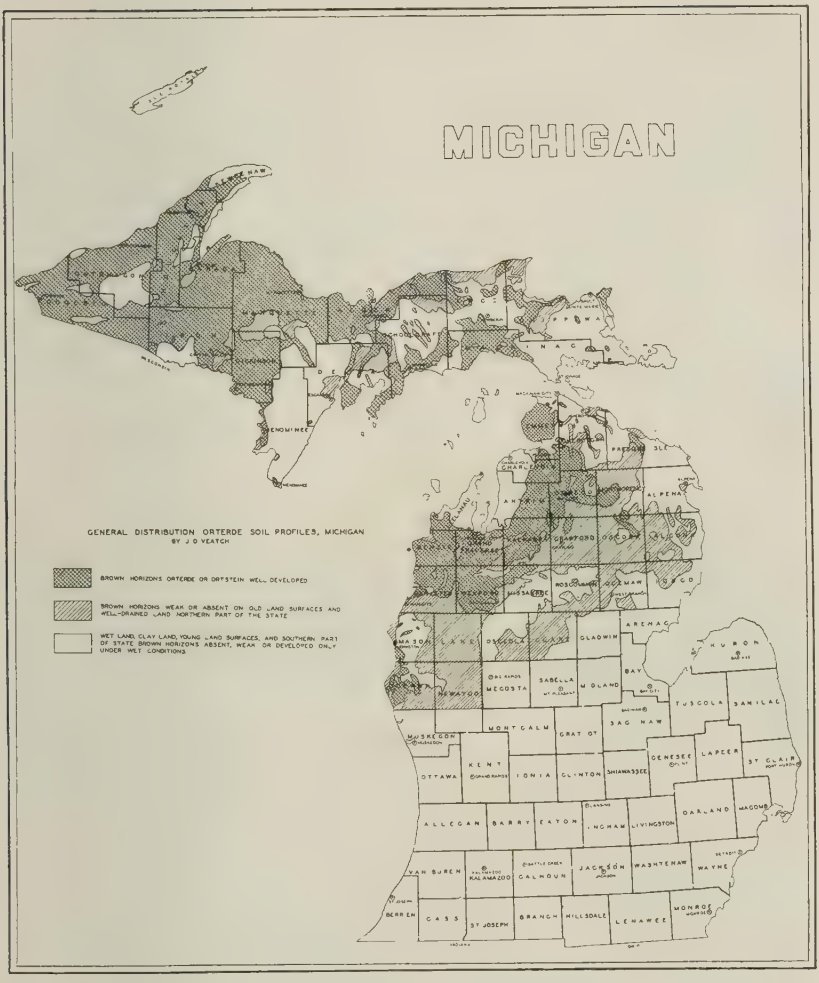

FIG. 3

mate since glacial times is the podsol profile which is common on dry or well-drained sandy land in the upper portion of the state. This particular soil profile is characterized by a gray or whitish highly leached horizon of sand or silt, underlain by a yellowish,

brown, or umber-colored horizon, in which the coloring matter is largely organic and which may contain a segregation of iron oxides and may or may not be cemented. This orterde or ortstein horizon occasionally reaches an extreme thickness of four or five feet, but is generally from six to twenty inches thick. If we assume cold conditions succeeding the final retreat of the ice sheet in the southern part of the state, tundra and podsol soils must have been present at one time. These have now completely disappeared except for relict features in some of the profiles. In the northern part of the Southern Peninsula the podsol profile on the drier or better-drained land probably occupies not more than half of the area, but in the Upper Peninsula it covers perhaps as much as 75 per cent. The simple geographic fact of distribution of this soil profile is evidence within itself of changes in climate. The distribution of relatively dry podsol soils is illustrated on the map, Figure 3, and the occurrence of an ortstein horizon on a high dry ridge of sand is illustrated in Plate I, Figure 2.

In short, the soil profiles of the state appear to exhibit as many features inherited from past climates as from the present. There are dry, hardwood podsols, such as the Kalkaska and Autrain soil types; profiles which are characteristic of waterlogged podsols and swamp soils, but which are now on dry sites; oxidized red clayey B horizons typical of a warmer climate than the present; and dark-colored humous soils which developed under a grass or treeless cover.

Michigan State College
East Lansing, Michigan

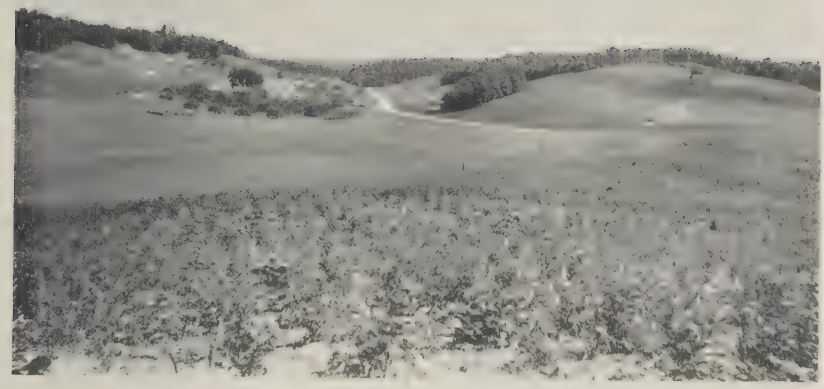

FIG. 1. Dry postglacial valleys, Leelanau County, Michigan

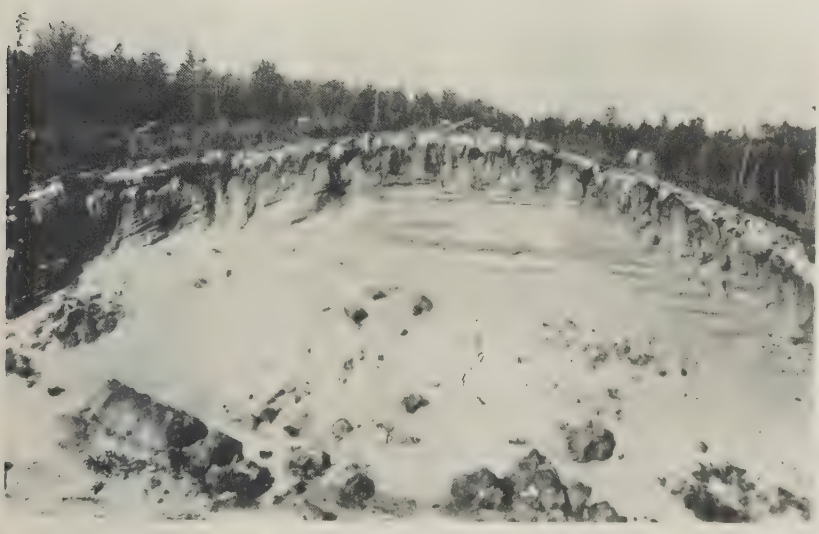

FIG. 2. A soil inherited from a past climate. A thick, leached gray horizon and a conspicuous ortstein, or sand hardpan, on a high, dry sand ridge. Ten miles south of Newberry, Luce County, Michigan

THE GEOGRAPHY OF A PART OF THE NORTHWEST CUMBERLAND PLATEAU OF KENTUCKY

PART I. PHYSICAL GEOGRAPHY *

LEONARD S. WILSON

INTRODUCTION

THE western limit of the Northwest Cumberland Plateau is the steep, heavily forested Pottsville escarpment which rises from the Highland Rim as a physical barrier to travel (Fig. 1). This escarpment provides a physiographic, as well as a geologic, boundary between the maturely dissected Cumberland Plateau and the lower lands to the west. It has served, also, from earliest times, as a barrier to the movement of the occupants.

The area is one of the more colorful historical parts of the United States. The majority of the inhabitants are direct descendants of the pioneer families who entered the wilderness, prior to 1800, through Cumberland Gap and moved northward along Wilderness Trail and Boone's Trace from the Valley of Virginia to isolated valleys of the plateau. Nor did the historical interest of the "Kentucky Mountains" culminate in the frontier era. In 1862 the northern advance of the Confederate armies was halted in this part of the plateau because of the inability of the supply divisions to maintain their routes of communication. This was caused in part at least by the mature dissection of the area.

Although long settled, this land is still in the process of expansion. Isolated from more recent lines of communication, the Northwest Cumberland Plateau has remained practically untouched by the spread of agricultural and industrial developments in eastern United States. Centrally located in the eastern part of the country,

* It is hoped that Part II, "Cultural Geography," will appear in a later volume in this series.

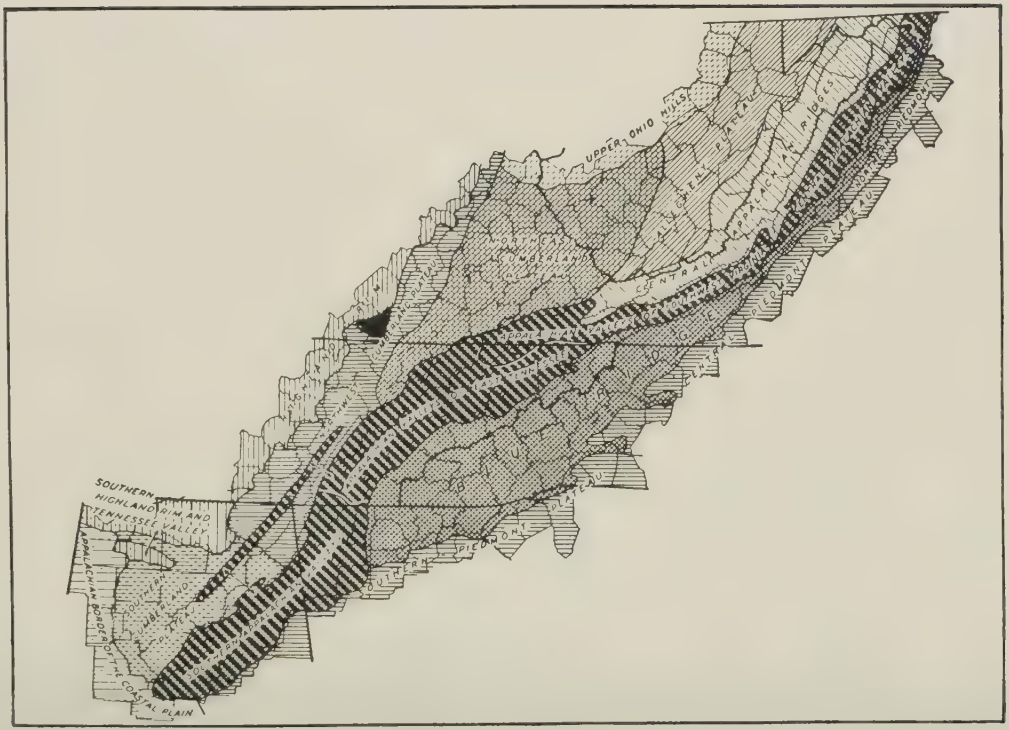

FIG. 1. Physiographic subregions of the southern Appalachians (from "Natural Land Areas," a map prepared by C. P. Barnes and F. J. Marschner, Bureau of Agricultural Economics, U. S. D. A., Washington, D.C.). The position of the area under discussion is indicated by the solid black triangle. Scale: 1 inch equals about 100 miles

it has been characterized as lying within the Cfa climatic zone.[1] Here the native vegetation is composed of mixed hardwood tree associations. In some sections this typical native cover is interrupted by stands of yellow pine, outliers of the southern pinery.

LIMITS OF THE AREA

The actual limits of the area under consideration do not correspond in any way to physical or cultural boundaries. Because of

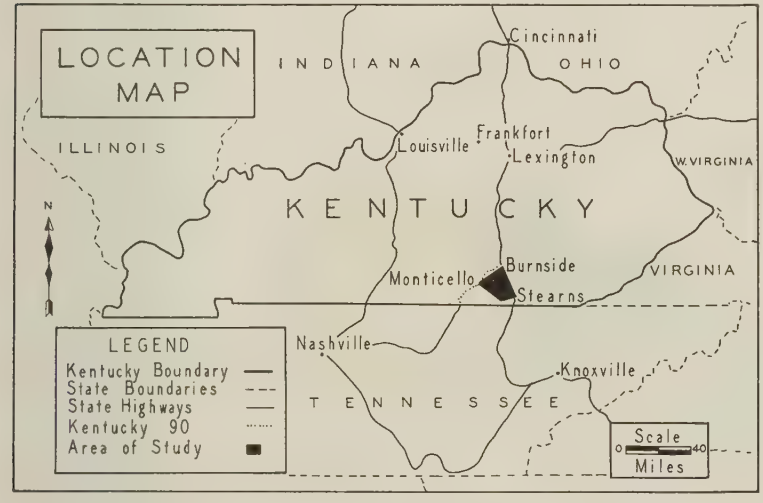

FIG. 2

the size of the Northwest Cumberland Plateau, about 6,000 square miles, as well as the absence of roads, the present study was restricted to a representative part of it. An arbitrary triangle of land lying between Burnside, Monticello, and Stearns was chosen [2] (Fig. 2).

The triangle covers an area of approximately 500 square miles. It consists of eastern Wayne County and the southern half of Pulaski

[1] BB'r according to Thornthwaite's classification of climates. See Thornthwaite, C. W., "The Climates of North America," *The Geographical Review*, Vol. 21, No. 4, pl. 3. 1931.

[2] Burnside is in Pulaski County; Monticello is the county seat of Wayne County; and Stearns is the largest town in McCreary County. The last two counties are in the southernmost range of counties in Kentucky; Pulaski is directly north and adjoins them.

County as well as the western half of McCreary County. The average elevation is about 1,200 feet, with an average local relief of 400 feet. Throughout the triangle the surface rock is Rockcastle Conglomerate, a resistant coarse-grained sandstone, deposited during the Mississippian period and later uplifted. Because of the dip of the deposits of the conglomerate, as well as of the underlying limestones, it is apparent that uplift was stronger on the western margin of the area than on the eastern. In spite of the direction of uplift the higher portions of the area are in the eastern section. This lack of relationship between the rock strata and surface elevations suggests that the surface was originally a peneplain.

DRAINAGE

The area in question is a part of the watershed of the Cumberland River, one of the largest tributaries of the Ohio River. In its upper reaches the Cumberland divides at Burnside into the North Fork and the South Fork. Here the South Fork flows in a meandering course northward from Tennessee, dividing the triangle into two nearly equal parts.

The principal tributary of the South Fork is the Little South Fork. Large meanders which occur in both streams indicate that at one time they had reached maturity. However, a more recent uplift of the plateau has upset the balance of these rivers, so that they are once more cutting downward in their beds. In places this intrenchment is very advanced; neither has reached maturity in the present cycle of erosion.

The smaller tributaries of these streams are all youthful. Draining only local portions of the area, they do not reflect the complex nature of the rivers into which they flow. In the western part of the area, where the Rockcastle Conglomerate has been eroded, exposing the underlying limestone deposits, karst drainage is prevalent. In nearly every instance the tributaries enter the major streams from a higher level, so that small waterfalls are characteristic of the triangle.

The flow of the streams is regular, with only minor seasonal changes in regimen. The maximum rise, known locally as a "tide," occurred in 1917, with a record increase in the level of the Cumberland River of 52.8 feet at Burnside. Fortunately the intrenched character of the major streams confined the floodwaters to the immediate vicinity of the river and, aside from covering the best

agricultural land, which is on the river flats, the inundation did little damage.

The drainage of the plateau proper is of a dendritic type. In the larger reëntrants into the plateau, however, erosion has advanced enough to permeate the limestone deposits, which are characteristic of the Highland Rim. Here mature karst features have developed. In all instances the karst drainage is close to the Highland Rim.

SURFACE CONFIGURATION

On the peneplain surface of the triangle the South Fork of the Cumberland River and its tributaries have been active agents of erosion, so that the surface is no longer that of a plain. In general, it has been lowered until the area presents the maximum of relief and the rounded interfluves associated with the mature stage of erosion.

Several kinds of surface, directly related to the underlying structure, can be observed. The plateau was originally capped by the Rockcastle Conglomerate. This rock, which extends from northeastern Kentucky through Tennessee, has been described as a heavy bed of sandstone or conglomerate. "It is characteristically a pebbly and gravelly conglomerate and varies in thickness from 100 feet to [nearly] zero at the margins of the plateau."[3]

The unevenness of the deposit is caused, in part, by erosion. Near the border of the plateau erosion has advanced to a later stage than within the area. Consequently the cliff-making rock has been stripped from the surface at an uneven rate. The presence or the absence of this deposit makes the greatest difference in the configuration of the surface and divides the triangle into two major districts. In sections where the conglomerate is a capping rock the cycle of erosion has been retarded, so that flat-topped interfluves, more characteristic of youth, are separated from mature valleys by vertical cliffs rising as much as two hundred feet (Pl. I, Fig. 1). Where the Rockcastle deposit has been removed, or reduced to a small remnant, the surface assumes a mature profile, with wider, flatter valleys and rounded interfluves (Pl. I, Fig. 2).

On the surface configuration map (Fig. 3) the extent of the conglomerate may be noted by the predominance of flat-topped interfluves in the area southeast of the South Fork of the Cumberland

[3] *The Geologic Atlas of the United States. London Folio, Kentucky*, U. S. G. S. (Library Edition, Washington, D.C., 1889), p. 3.

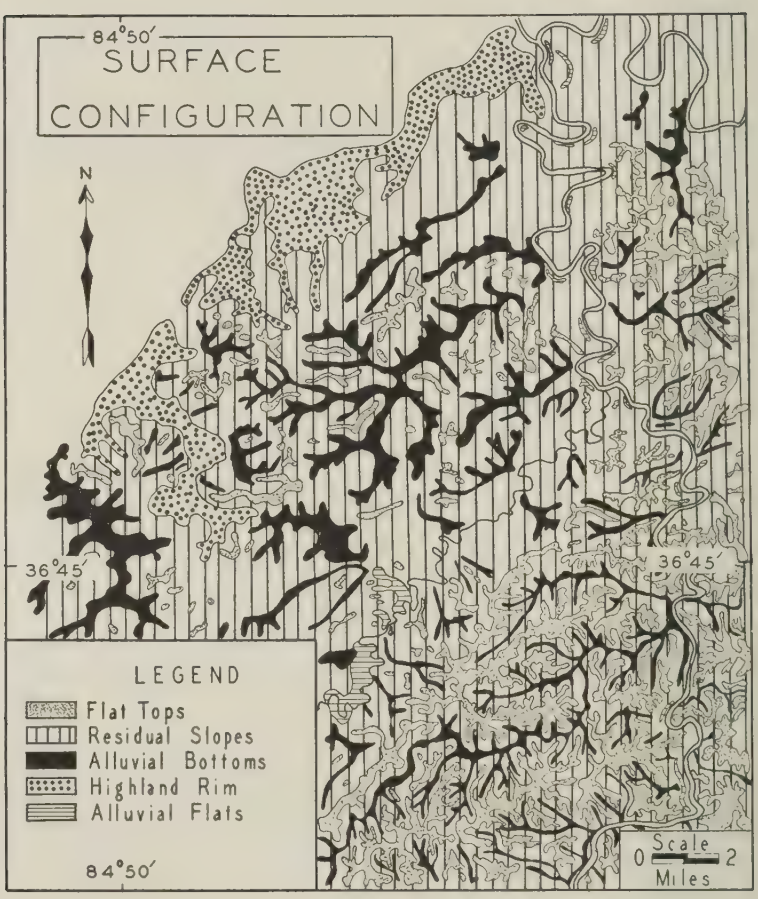

Fig. 3

River. Though it is true that a number of flat-topped areas are represented on other parts of the map, the greatest concentration appears in the southeast. In the vicinity of the river, however, mature rounded tops indicate the lack of conglomerate.

The Rockcastle Conglomerate is underlain by two kinds of limestone, the St. Genevieve and the St. Louis. In areas where the conglomerate has been removed these form the surface rocks. There is

little or no appreciable difference in the surface configuration in the parts of the triangle dominated by either of these deposits. Both have essentially the same resistance to erosion and, as a result, similar profiles. The basic difference between the flat-topped interfluve areas and the districts of residual slope is closely related to these two rocks.

In addition to these two major surface divisions smaller amounts of land have been classified as colluvial slopes. This subdivision is not directly related to surficial rock deposits, but implies that the slopes result from soil wash and are gentler. It breaks the otherwise sharp line that separates the residual slopes from the alluvial lands.

Alluvial flats and alluvial bottom lands constitute the two final subdivisions of surface configuration. The former areas are restricted to the immediate vicinity of the two major streams and, in general, are the best agricultural lands. They are not only highly fertile, but have the added advantage of lying in comparatively large level tracts. The alluvial flats are roughly scroll-shaped, as may be seen on the map (Fig. 3), and are typical of the mature stage of stream erosion. It is possible to divide these deposits into upper and lower flats, depending upon the cycle in which they were laid down. Briefly, the upper flats are older, less fertile areas related to the deposits of the Little South Fork and the South Fork of the Cumberland River and were deposited prior to the last uplifting of the plateau. The lower flats represent recent deposits made since the last uplift; they are separated from the upper flats by a vertical distance of approximately ten feet. These flats are affected by the annual rise of the river, and in this respect differ from the upper flats; they are more fertile but smaller.

In contrast to the alluvial flats the alluvial bottoms are small and are related to the minor tributary streams. Although these areas are also the result of stream deposit, they differ from the flats in that they are narrow and are confined to the valley bottoms. They are composed of a thin veneer covering the underlying rock. Replenished each year by the overflowing of the creeks, they, like the flats, are classed as superior agricultural lands. Where the Rockcastle Conglomerate controls erosion these bottoms are very small, whereas in the round-topped areas indicated by the residual slope classification they are somewhat larger. On these lands and on the alluvial

flats and alluvial bottoms is found the only soil capable of supporting continuous agricultural production.

SOILS

Most of the soils of the triangle are residual; the patches of alluvial soils are confined to the vicinity of the streams. The residual soils were formed by the weathering of sedimentary rocks, which inherently are not capable of producing fertile soils.[4]

All soils derived from the Rockcastle Conglomerate are thin and sandy. They tend to dry out rapidly because of their porous nature; this gives the plateau an aspect of moisture deficiency during dry weather. In contrast, during and immediately after precipitation these areas seem to be saturated. Because of a small amount of clay in the soils they are very slick when wet. They range from a thin layer to eight inches. Confined to the plateau top, they are deficient in humus, highly leached, and light yellow. These soils are entirely unsuited to present-day methods of agriculture.

The soils of the residual slope areas, produced by the weathering of limestone, are usually resolved into heavy soils and are underlain by dark red clays. Good drainage is typical of these areas. The soils, which have been classified as sandy loams, rest on tight clay subsoils.[5] Although they cannot be considered first-class agricultural soils, it is possible to produce good crops on them in areas of little slope. Unfortunately, the latter condition does not prevail in the triangle, where, being located on the valley slopes, they wash badly, especially under agricultural use. In many parts the entire A horizon has been removed by sheet erosion and the bright red subsoil exposed.

Erosion is a very serious problem. Both sheet and gully erosion are year-round processes. In spite of attempts by the state to exercise control, little has been accomplished. Sheet erosion may be encountered in all sections of the triangle; gully erosion is characteristic of all but the alluvial soils (Pl. II, Fig. 1). In many parts crop land

[4] In the absence of any soil survey for the counties under consideration a generalized distribution of soils may be inferred from the surface configuration map (Fig. 3).

[5] A more detailed description of the chemical components of these soils may be found in S. D. Averitt, *The Soils of Kentucky*, Kentucky Agricultural Experiment Station, State University, Lexington, Kentucky, Bull. 193. Lexington, Kentucky, 1915.

has been seriously reduced by the removal of the top soil. In these localities the land is promptly abandoned. No attempts are made to prevent such land from eroding further.

From these washing slopes, and from the streams as well, an apron has been built up around the base of each ridge and outlier. The name "colluvial soils" has been given to this combination of local and river deposits. They correspond closely to the classification "colluvial slope" and may be characterized as being light yellow sandy clay. A large percentage of the agricultural production is carried on in these areas.

Alluvial soils are found in the valley bottoms; they are the only ones within the triangle capable of supporting agriculture year after year. Deposited by streams during flood, they receive a fresh supply of soil and organic material which maintains their fertility. Thus they reflect the heterogeneous character of the rocks through which the streams flow. They are a light brown sandy loam.

The inhabitants of the area realize that these soils are superior, and their excellence is reflected in the increased price of alluvial lands, in spite of their being the most isolated. In many parts of the triangle attempts have been made to enlarge the available alluvial deposits. This is done by throwing a rock or log dam across the bed of a creek which drains the hollow. During spring floods these obstructions check the flow of water and cause the transported material to be deposited above the dam (Pl. II, Fig. 2). Over a period of years the creek may build up the deposits to a height of ten or fifteen feet. In one hollow which has been settled well over a hundred years the farmers no longer cultivate the slopes, but prefer to concentrate their efforts on the superior alluvial soils obtained in this manner.

CLIMATE AND VEGETATION

The climagraph presented indicates that the climatic conditions are representative of a Cfa (BB′r) type of climate (Fig. 4). The precipitation is regular, with no pronounced dry season. The mean annual temperature of the triangle is between 55.1° F. and 57.5° F. The warmest weather is in July; the coldest, in February. Usually the temperature is mild, although days of extreme heat (above 100° F.) and cold (below 0° F.) do occur. Data on frost and length of growing season indicate that the average number of continuous frost-free days is 189.

Although the cover map (Fig. 5) reflects the broader climatic characteristics of the area, the detailed distribution of vegetation is more closely related to the edaphic elements. The outcrop of the Rockcastle Conglomerate is marked by a characteristic growth (Pl. III). On this land may be found the true mountain flora.[6]

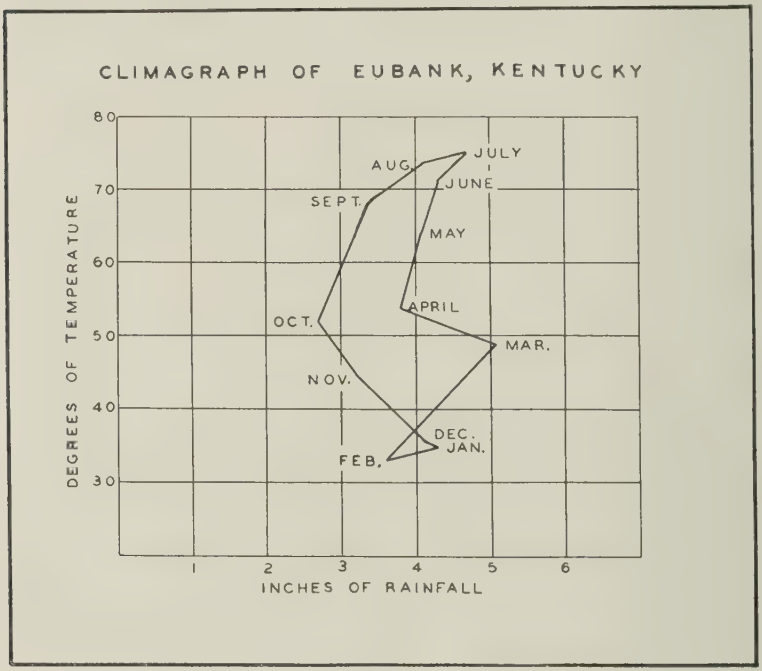

Fig. 4

Conspicuous members of this association include white pine, yellow pine, chestnut, and gumwood. In the valleys spruce, hemlock, and pine are most common. The smaller trees are rhododendron, laurel, sourwood, and mountain magnolia, known locally as "cucumber tree." In addition, huckleberry, blackberry, and trailing arbutus are present. Arbutus clings to the cliffs of the Rockcastle Conglomerate and is not found in adjoining areas.

[6] Miller, A. M., *The Geology of Kentucky*, p. 115. Department of Geology and Forestry, University of Kentucky, Lexington, Kentucky, 1919.

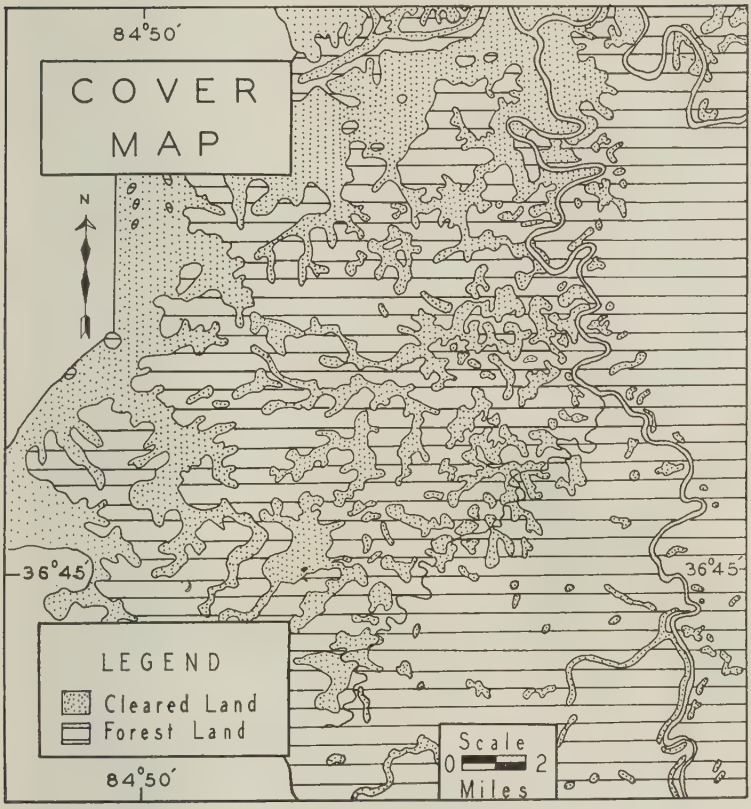

FIG. 5

Parts of the triangle not controlled by the conglomerate support a normal hardwood growth. The dominant trees are as follows:[7]

Tree	*Percentage*
Hickory	18.1
Chestnut-oak	33.9
Basswood	10.0
Yellow poplar	29.0

[7] Figures taken from *Forestry in the Economic Life of Knott County, Kentucky*, Kentucky Agricultural Experiment Station, University of Kentucky, Bull. 326. Lexington, Kentucky, 1932.

Other trees present in small numbers are black oak, white oak, black gum, and red maple. Hemlock, also, is sparse, and a marked correlation between it and local limestone outcrops was noted. The true chestnut, which was formerly an important member of the association, has been almost entirely removed by blight. According to the University of Kentucky, 97 per cent of the few remaining trees are seriously infected.

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Northfield, Minnesota

FIG. 1. Outcropping of Rockcastle Conglomerate, with characteristic development of vertical cliffs and flat-topped interfluves

FIG. 2. An outlier of Rockcastle Conglomerate, with the flat-topped area reduced to a remnant surrounded by broad mature valleys

FIG. 1. Gully erosion on residual soils near Parker's Lake

FIG. 2. Soil dam showing the deposition of soil above it

Vegetation characteristic of the flat-topped interfluve areas

PROTOTRETA, A NEW GENUS OF BRACHIOPOD FROM THE MIDDLE CAMBRIAN OF MONTANA

W. CHARLES BELL

THE genus *Acrotreta* was described in 1848 by Kutorga, who assigned three species to it. Of these, *A. subconica* Kutorga from the Ordovician of Russia was selected by Hall and Clarke in 1892 as the genotype. Kutorga based his description of *A. subconica* on four specimens, which showed only the exterior of the shell; no other examples of the species have since been collected from either the type locality or strata in Russia. Prior to 1912 several species from the Cambrian and lower Ordovician rocks of North America had been assigned to the genus on the basis of external similarity. The internal features of some of these species were known and came to be accepted by American paleontologists as characteristic of *Acrotreta*. As a result, when Walcott prepared the most recent diagnosis of the genus, in 1912, he based his definition almost entirely on North American species.

J. A. Thomson (1927, p. 120) states in a discussion of the genus concept as related to the brachiopods: "The importance of a full knowledge of the genotype . . . becomes evident, for generic classification of a species is not so much a process of ascertaining whether the species possesses the characters which have been claimed to hold good for the genus, as a process of comparing the species with the genotype in order to estimate its probable relationship through descent." The question therefore arises: "What are the characteristics of the genus *Acrotreta* as typified by *the genotype?*" Unfortunately, our incomplete knowledge of *A. subconica* precludes a satisfactory answer. Upon what basis, then, have there been assigned to the genus *Acrotreta* some fifty-six species and eleven varieties, almost without exception differentiated by means of variations in the external characters of the ventral valve? Walcott, who is entirely

responsible for the present constitution of the genus, included within it species to which the following definition could be applied: Ventral valve corneous, more or less highly conical, and penetrated at or near the apex by a minute foramen, below which the posterior surface of the cone is more or less flattened or grooved; dorsal valve flat or slightly convex. Obviously this definition takes into consideration only external characters and is based on the supposition that superficial external resemblance to one another among a number of species constitutes generic relationship. In the writer's opinion the similar external form common to most species of *Acrotreta* may well have resulted through polyphyletic development.

Among the brachiopods internal characters are admittedly of superior value in indicating relationships. The internal characters of *Acrotreta* have been essentially disregarded, so far as application to classification is concerned. From Walcott's figures it is apparent that not all species of the genus have similar interiors. It is also apparent that the species can be separated into several groups, within each of which the internal characters are fairly constant. The writer is confident that these groups, which probably are of generic rank, will be found to possess greater stratigraphic significance than the genus *Acrotreta* as now defined.

The incompleteness of our present knowledge of the orders Atremata and Neotremata is due primarily to mechanical difficulties in the technique of preparation. The shells are small (2–10 mm. in length), extremely delicate structurally, and calcareophosphatic in composition. Cleaning the shells with an acid or a base is seemingly impossible, and mechanical methods are successful only when the matrix is relatively nonresistant to the needle. In the writer's experience serial sectioning is the only method which will yield a knowledge of internal characters in almost all cases. Apparently this method has not heretofore been used in studying the Atremata and the Neotremata, and it is recommended as a means of increasing our knowledge of these groups.

On the supposition that characters of generic rank are to be found in the dorsal interior of the Neotremata the writer proposes to describe a new genus, *Prototreta*, which is externally a homeomorph of *Acrotreta*. Because not all the known species have been adequately studied, and because the ventral interior is not yet well known, at present it is impossible to give a complete description of the genus.

In this preliminary announcement it is planned to outline the principal generic characters and to designate and figure a genotype.

GENERIC DIAGNOSIS: *Ventral valve.* — Calcareophosphatic (collophane), highly conical, and penetrated at the posterior side of the apex by a minute foramen, below which a groove extends to the margin of the valve (Pl. I, Figs. 1–2). Interior unknown. *Dorsal valve.* — Flat or gently convex, with a minute marginal apex (Pl. I, Fig. 3). Interior (Pl. I, Fig. 4) with posterolateral margins thickened into flat triangular areas (for each of which the name *proparea* [1] is proposed), oriented strongly anacline, which border a broad central groove whose margins diverge anteriorly from the apex approximately at right angles; prominent median septum which, in anterior part of valve, expands laterally and vertically into a strong plate, from which extend six or more finger-like projections. Muscle scars diagrammatically represented in Plate I, Figure 5.

Diplotype. — **Prototreta trapeza,** sp. nov. (Pl. I, Fig. 4); catalogue number 1535, Museum of Paleontology, Montana State University, Missoula, Montana.

Occurrence. — Middle Cambrian, *Bathyuriscus* zone in basal part of Meagher limestone, Nixon Gulch, approximately six miles north of Manhattan, in SW. ¼ Sec. 23, T. 2 N., R. 3 E., Three Forks Quadrangle, Montana. Locality 45, zone 3a, Montana Bureau of Mines and Geology (= locality 19z, U. S. Nat. Mus.), which is at the same stratigraphic position as, and 1,500 feet N. 12° W. from, locality 45, zone 3, of Deiss (1936, p. 1314).

The dorsal valve of *Prototreta* is morphologically unique. Its particular type of posterior margin, called *pseudointerarea* by Schuchert and Cooper (1932, p. 20), simulates closely the pseudointerarea found in the ventral valves of *Obolus* and *Lingulella* of the Atremata. It is assumed that in the Atremata the pedicle protruded between the valves through the groove bordered by the propareas; but it is believed that in the Neotremata, to which *Prototreta* apparently belongs, the pedicle protruded through the foramen at the apex of the ventral valve. Both a ventral foramen and a dorsal groove, which is apparently analogous to the ventral pedicle groove of the Atremata, appear in *Prototreta.* At present the writer cannot account for this anomalous condition. More must be known concerning

[1] The term "proparea" is proposed as a descriptive name for each half of the pseudointerarea when a pedicle groove divides it into two parts.

the ventral valve of *Prototreta* before even a tentative explanation can be made.

Many species of *Acrotreta* have a median septum in the dorsal valve. This septum, which is described and figured by Walcott as a simple, straight, low ridge of varying length, has been practically ignored in classification. Nearly all the knowledge concerning it has been derived from internal molds. The development of the septum in *Prototreta* is striking and, to the writer's knowledge, without parallel in any other brachiopod. In life the structure extended into the interior of the ventral valve, but its function is not clear. Muscle impressions apparently are present upon the septum (a condition unknown in *Acrotreta*) at the base of the expanded plate; but no roughened areas, indicating the former attachment of tissue, have been observed upon the finger-like projections.

Scars which unquestionably served as points of muscle attachment in the dorsal valve have been observed only on the visceral face of the thickened pseudointerarea. One pair of vaguely outlined scars adjoin the inner margins of the propareas. Another pair, clearly outlined and deeply incised, occur below the lateral visceral margins of the "pedicle" groove. This muscle pattern differs greatly from that regarded by Walcott as typical of *Acrotreta*. He noted the presence of one pair of muscle *tubercles* at the posterolateral margins of the valve and of another pair bordering the median septum near the center of the valve.

Prototreta has the external characters of *Acrotreta* as conceived by Kutorga. It may be claimed that *Prototreta* should therefore remain included in *Acrotreta* until it can be proved that the interior of *A. subconica* Kutorga is distinct from that of the Montana genus. The writer grants the justice of this claim, but offers the following defense. If he is correct in his belief that generic characters are to be found in the morphology of the dorsal interior, then more than one genus is included among the species now assigned to *Acrotreta*. Certainly the species from Utah, assigned by Walcott to *Acrotreta*, possess dorsal interiors radically different from those of *Prototreta*, and both differ from the species of the Appalachian province. In the writer's opinion it is desirable to separate as soon as possible the *Acrotretae* of North America into more accurately defined generic groups, and thus to make them valuable for stratigraphic correlation. Because of their unreliability in correlation they are at present

almost ignored by Cambrian stratigraphers. If, in the future, one of the new genera is found to be identical with *A. subconica* from Russia, the new name may be relegated to the synonymy of *Acrotreta*.

ACKNOWLEDGMENTS

The writer is grateful to Professors G. M. Ehlers and E. C. Case, of the University of Michigan, for kindly advice and criticism during the writing of this paper. The specimens studied were generously loaned by the Montana Bureau of Mines and Geology.

University of Michigan

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EXPLANATION OF PLATE I

All specimens figured are preserved in the Museum of Paleontology, Montana State University, Missoula, Montana.

Prototreta trapeza, gen. et sp. nov.

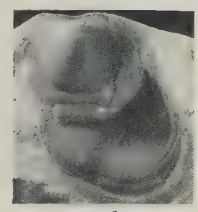
Figs. 1–2. Apical and posterior views of an almost perfect ventral valve. Note foramen on posterior side of apex in Figure 2. × 6 (No. 1534a)
Middle Cambrian, Pentagon shale; locality 26, zone 4, Continental Divide, Lewis and Clark range, above head of South Fork of Lick Creek, in Sec. 18, T. 24 N., R. 11 W., Montana

Fig. 3. Apical view of a well-preserved dorsal valve, showing the deep sulcus, apparently a specific character. × 8 (No. 1534b)
Locality 26, zone 4

Fig. 4. Interior of a dorsal valve, showing propareas, groove, and expanded median septum. × 9. Diplotype (No. 1535). This valve apparently is identical with, but better preserved than, dorsal valves from locality 26, zone 4.
Locality 45, zone 3a (see page 405)

Fig. 5. Diagrammatic representation of the pseudointerarea and expanded median septum characteristic of *Prototreta*. Note muscle scars, which are crosshatched; those on septum are doubtful

Fig. 6. Drawings of serial sections through a dorsal valve of *Prototreta trapeza*



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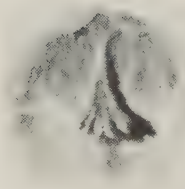

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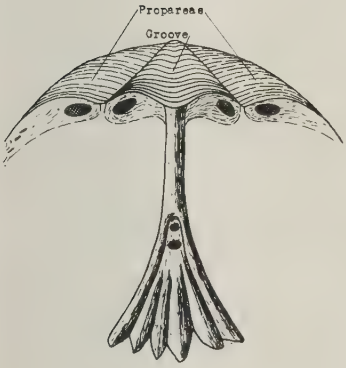

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Prototreta trapeza, genotype of a new brachiopod genus from the Middle Cambrian of Montana

ACIDIZING IN MICHIGAN, 1932–37

LEONARD C. CHAMBERLAIN, JR.,* AND PAUL E. FITZGERALD†

INTRODUCTION

ACIDIZING had its early commercial development in Michigan. The successful treatment of The Pure Oil Company's Fox No. 6 in the Chippewa-Greendale pool began in February, 1932, the industry which is now known as "acidizing." In the five years since this well was treated the process has spread to every oil field in the United States, Canada, and Mexico where production occurs in formations that are susceptible to it. In 1936 there were approximately 5,000 treatments, which used 10,000,000 gallons of acid.

HISTORY

The early history and the results of acidizing in Michigan were described by Newcombe (2), Covell (1), and others. Comments and speculations made in these papers yield an interesting basis for a comparison of equipment, technique, and materials used then and now. Figure 1, Plate I, shows one of the original treating units. Figure 2, Plate I, illustrates one of the present units, into which is built the experience of the last five years. It is faster, more reliable, carries more acid, and is equipped with pumps capable of larger volume and higher pressure. Likewise, stations have changed from the temporary quarters used in 1933, as shown in Figure 3, Plate I, to the permanent type exemplified by the new station at Mt. Pleasant, Michigan, as shown in Figures 1–2, Plate II.

It was agreed then, as it is now, that acidizing made for worthwhile increases in yield in most Michigan wells, except in those producing from the Berea sandstone. It was pointed out, however, that re-treatments were not so successful as first treatments; and speculations were advanced on the possibilities of the presence of "second-

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ary reactions" and on their effect in wells which were shut in for 24 to 36 hours after treatment.

Since then the answer to successful re-treating has been demonstrated to be a matter of directing the acid into tighter, unspent areas and away from the porous section which was opened by the first treatment. The secondary reactions have been found to consist mainly of a re-precipitation of metal hydrates and calcium carbonate. The metal oxides are dissolved from the formation by the fresh acid and are dropped in flocculent form whenever the acid remains too

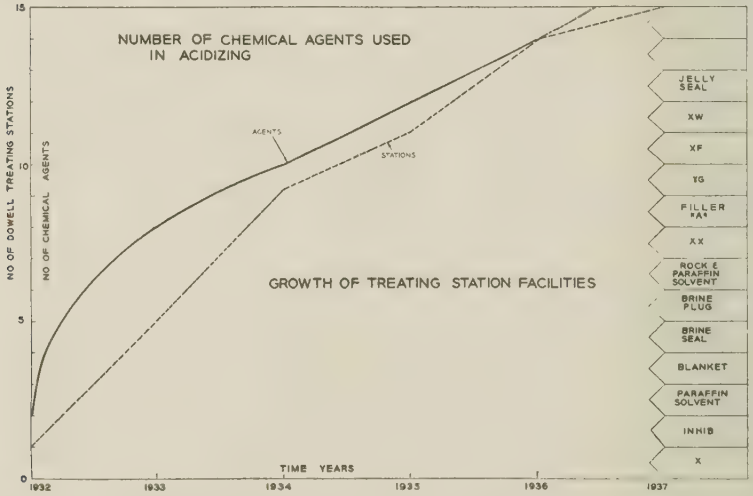

Fig. 1. Yearly growth of stations and chemical agents

long in contact with the limestone. The calcium carbonate is first dissolved by long contact with the carbon dioxide generated from the primary reaction, and is laid down again when the pressure is finally released at the resumption of production.

The chief differences, then, between acidizing as first used and as now practiced in Michigan are the methods of directing acid into the tighter, more saturated portions of the formation and the combination of newer acids and technique to effect a much shorter treatment, safer from the dangers of re-precipitation. Wells are now put into production in Michigan within less than two hours after acidizing.

In 1932 about six chemical agents were applied in acidizing.

Each year since an average of two additional chemicals has been added, which has improved the scope of this service. There are now some fifteen different chemical agents regularly required in acidizing oil and gas wells.

Figure 1 shows the yearly record of the growth of acidizing; one curve indicates the number of chemical agents in use and the other the number of treating stations established. To the inhibited hydrochloric acid [1] and the well-known "Paraffin Solvent" and "Blanket," [2] with which the start was made, there were soon added the "Brine Seal" for prevention of water increase; "Brine Plug" to prevent action on lead plugs; and a mixture known as "Rock and Paraffin Solvent." Then came the addition of bifluorides [3] to increase the action of acid on siliceous and dolomitic limestones; the Lime Filler "A" as a directing agent in re-treatments; and "XG," [4] a special acid for "gyp" removal. Finally, there were put into use the "XF" [5] and "XW" acids, containing phenol, cresols, and alcohols, to facilitate penetration and subsequent removal of acid; and the "Jelly Seal," [6] which has largely replaced Filler "A" and which is the most successful aid yet introduced for acid direction in re-treatments.

Similar strides have been made in testing and research. From reliance on chemical analyses and solubility tests acidizing has gone to controlled flow tests on cores to determine the advisability of the process and, to some degree, the type of agent and the technique to be used. Likewise, research efforts have increased until there are now three fully equipped laboratories, where before there was one such, devoted to the maintenance and improvement of acidizing processes. Figure 3, Plate II, shows one of these laboratories in which may be seen a battery of core-testing apparatus for checking acidizing procedure.

[1] Grebe, J. J., and Sanford, R. T., "Treatment of Deep Wells." September 13, 1932, U. S. 1,877,504.

[2] Grebe, J. J., "Method of Treating Wells with Acids." June 27, 1933, U. S. 1,916,122.

[3] Heath, Sheldon, and Fry, William, "Acid Treating." August 20, 1935, U. S. 2,011,579.

[4] Grebe, J. J., "Treatment of Wells." January 29, 1935, U. S. 1,989,479.

[5] Chamberlain, L. C., "Treatment of Wells." December 17, 1935, U. S. 2,024,718.

[6] Grebe, J. J., and Stoesser, S. M., "Treatment of Deep Wells." April 23, 1935, U. S. 1,998,756.

SOME MICHIGAN DATA

Only a few acid tests have been made on cores from Michigan oil-producing formations. Some cores are available which are large enough to provide samples of a size suitable for testing. The interesting results obtained from such samples are exemplified by the following summary of data on two Dundee cores furnished by a major oil company (Fig. 2).

The very great increase in permeability obtained by a doubling of the porosity indicates that the pores, though large, were constricted. Poiseuille's law would indicate a fourfold increase of permeability if

CORE Nº 51	WEIGHT OF CORE IN GRAMS	VOLUME OF CORE IN CC	POROSITY	PERMEABILITY (MILLIDARCIES)	INCREASE FROM ACIDIZING
BEFORE ACIDIZING	31 953	13 8	9 43	120	
AFTER ACIDIZING	29 450	.3 5	18 5	55,000	458 TIMES
CORE Nº 53					
BEFORE ACIDIZING	28.858	11.8	4 75	12	
AFTER ACIDIZING	27. 804	11.65	10.7	4500	3750 TIMES

COURTESY PURE OIL COMPANY

FIG. 2. Acidation of Dundee cores from Greendale, Michigan

the pore volume of uniformly sized pores was uniformly doubled. The vast difference between this theoretical 4 and the 3,750 times actual increase is proof that a small amount of material is almost completely blocking the flow channels, and is a partial explanation of the fact that results from acidizing have been far above expectation.

The type of core used is shown in Figure 1, Plate III. It is one inch in diameter and one inch long. The exposed crystals have been only slightly attacked by the acid. X-ray analysis proves these crystals to be pure dolomite, embedded in a matrix of calcite. The acid eats out channels around the blocking crystals. Figure 2, Plate III, is a photomicrograph of the face of an unacidized core; Figure 3, Plate III, that of an acidized one. The fine structure of the calcite is apparent in Figure 2, Plate III, whereas in Figure 3, Plate III, the calcite is dissolved away, a process that exposes the sharp corners of the less soluble dolomitic crystal.[7]

[7] These are not photographs of the same spot before and after, but are typical.

In 1935 the average percentage increase for treatments in Michigan was estimated at 417 (3). Since then some 700 additional acid treatments have been given. Complete records of 12 per cent of these wells were available to the authors in calculating the results that appear in Figure 3, along with other data of interest for the

	FOR-MATION	GENERAL ANALYSIS	FIELD	AVGE % INCREASE	TREATING AGENTS & REMARKS
DEVONIAN SYSTEM	TRAVERSE	LIMESTONE AND DOLOMITE 25-90% $CaCO_3$ 78-98% SOLUBLE	OGEMAW	310	X AND XX EARLY TREATMENT
			EDMORE	400-800	
			HART		
			CHIPPEWA-GENEVA	650-3900	
			MUSKEGON		
	DUNDEE	USUALLY LIMESTONE 70-98% $CaCO_3$ 2-4% $MgCO_3$ 85-99% SOLUBLE SOMETIMES DOLOMITIC	CHIPPEWA GREENDALE	2024	XF ALMOST ANY TYPE ACID IS SUCCESSFUL
			DENVER	1360	
			PORTER	1413	
			OGEMAW	310	X AND $\underline{XF}$
			BEAVERTON	400	XF
			ARENAC	620	XXF, XXWF, XF
	U MONROE	DOLOMITE 54% $CaCO_3$ 44% $MgCO_3$ 2% SILICEOUS MATERIAL	SHERMAN	132	XF, XXF, XXWF VERY TIGHT $\underline{XWF}$ BEST AT PRES
			VERNON	4494	$\underline{XF}$ AND XXWF TIGHT
			CRYSTAL	613	XF AND XXF TIGHT
			MUSKEGON		X

Fig. 3. Data on acidizing in Michigan oil fields

various fields. These results average 964 per cent increase. The Sherman field in Isabella County west of Mt. Pleasant is a new one in which the best treating materials and procedure are still being determined.

Greatest percentage increases are found in the smaller wells. All treated wells that make over 100 barrels a day, except those in the Porter Field, have an average increase of 155 per cent. Porter wells of 100 barrels or more average 765 per cent increase, whereas

those wells under 100 barrels a day, in all Michigan, have averaged 1247 per cent since 1935. Quick-penetrating acids which enter and return from the formation more easily, gel compounds used for directing agents in re-treatments, and abolishment of shut-in periods are largely responsible for the increased returns of the last two years. Phenol, cresylic acid, and various aliphatic alcohols have been used in the HCl to produce these new effects.

The study of decline curves constitutes the best method of arriving at the real value of acidizing. These curves are made from

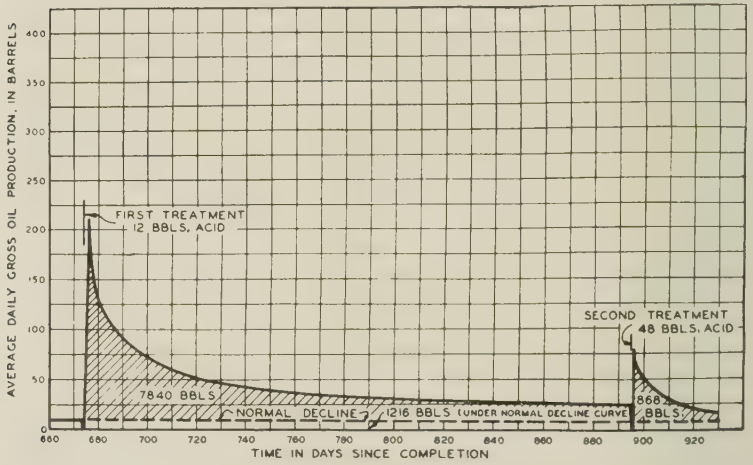

Fig. 4. Decline curves, Covell No. 1

production figures collected over a long period and give the total increased oil output for that period. In the figures shown the normal decline is designated by the dotted line and the increased oil by the crosshatched portion. Many such curves have already been published (1, 4).

In Figure 4 two acid treatments are demonstrated as having added 8,700 barrels of oil over and above the 1,216 barrels indicated by the normal decline curve. At the normal rate it would have been necessary to operate this well five years to get what it produced in the 260 days following treatment.

The well from which the data in Figure 5 were derived produced

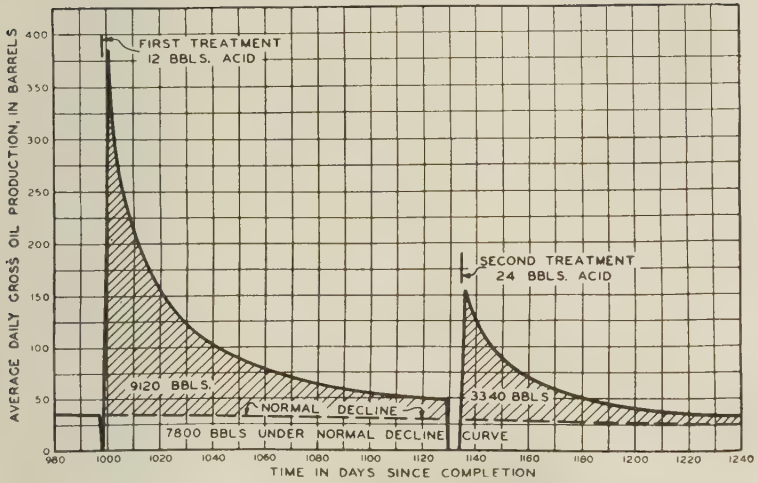

Fig. 5. Decline curves, Covell No. 1

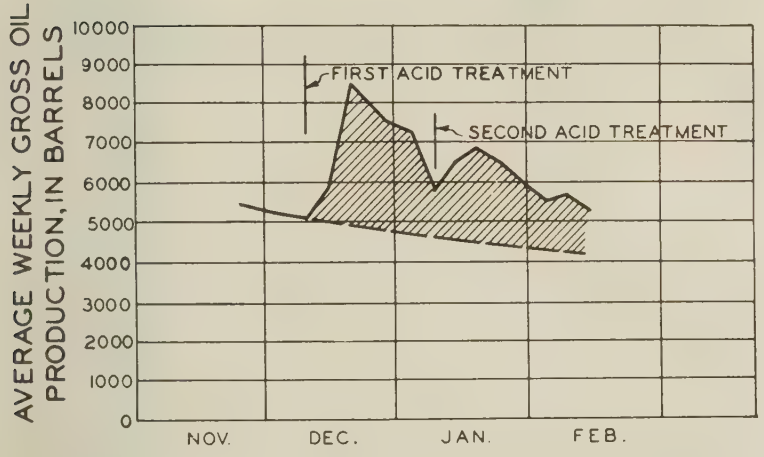

Fig. 6. Decline curves, Arenac field

12,460 barrels over and above the 7,800 barrels indicated for the period of 240 days.

The Arenac Well, from which the data in Figure 6 were derived, recovered during the sixty days following the treatments approximately 17,000 barrels above the normal expected production.

Figure 7 demonstrates what acidizing often does for a new well which comes in making uneconomic amounts of oil. The first acid

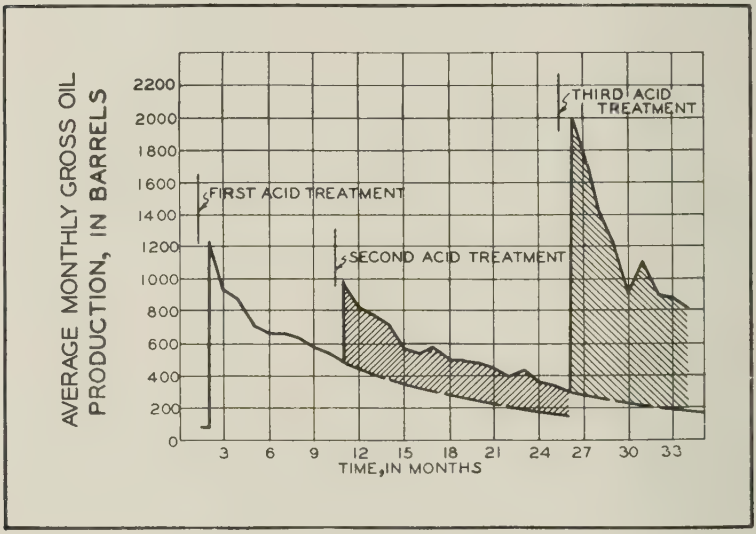

Fig. 7. Decline curves, Porter field

treatment, given before a decline curve had been established, made the well a commercial producer. The second acidizing added 3,750 barrels in 15 months, and the third gave an even greater return, 6,400 barrels in 8 months.

CONCLUSIONS

Approximately 2,100 acid treatments have been given in Michigan, or an average of 1.5 for each of the 1,400 commercial oil wells that have produced from limestone formations. It is estimated that 80 per cent of all treatments are commercially successful, and that, in proved fields, more than 90 per cent are successful. The general

statement holds true today that 75 per cent or greater acid solubility of the producing rock formations is desirable for good results from acidizing and that only a few exceptions have profited from acidizing wells of 25 per cent or less solubility. The rise in the average increase production due to acid treatment is attributed to experience which operators have gained in knowing when a well is a fit subject for acidizing, to new methods of directing acid to unspent production areas, and to new acid solutions and technique which have made it possible to shorten the time of shut-in from thirty-six hours to a matter of minutes.

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2. Newcombe, R. B. Acid Treatment for Increasing Oil Production. Oil Weekly, 69 (May 29, 1933): 19–26.

3. —— Mechanics of and Economical Value of an Acid Treatment of Oil and Gas Bearing Formations, also a Summary of Oil and Gas Developments in Michigan, including Rotary Drilling. Released to Oil and Gas Journal June 6, 1935.

4. Zavoico, B. B. Geology and Economic Significance of Central Michigan Field. World Petroleum, 6 (May 1935): 309–324.

PLATES I–III

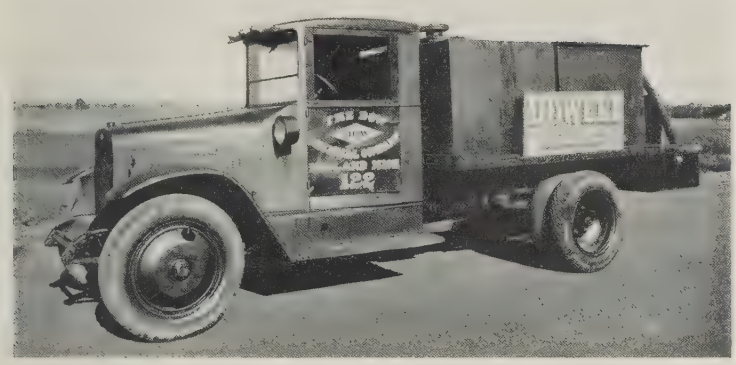

FIG. 1. Original treating unit

FIG. 2. Present treating unit

FIG. 3. Temporary field headquarters

FIG. 1. Mt. Pleasant treating station

FIG 2. Mt. Pleasant acid storage

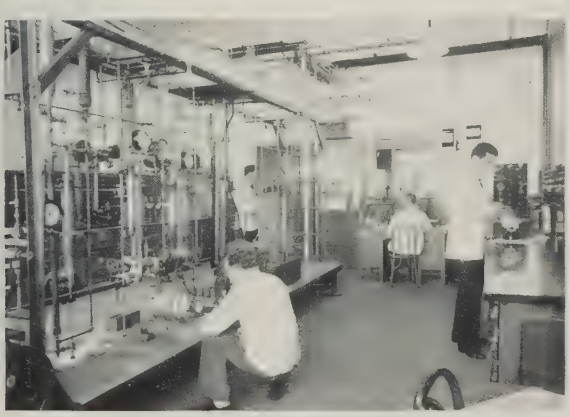

FIG. 3. Dowell laboratory

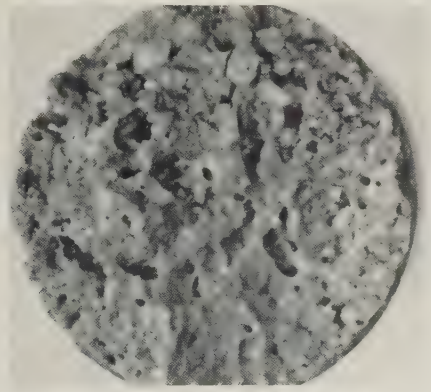

FIG. 1. Michigan Dundee core 51 after acidization

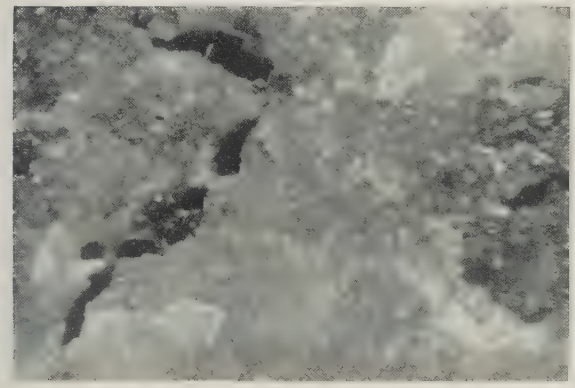

FIG. 2. Photomicrograph of core unacidized

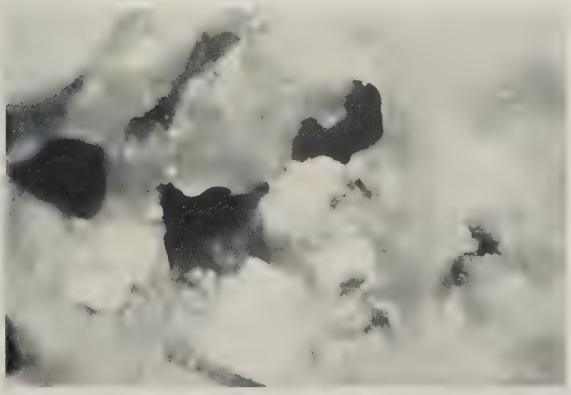

FIG. 3. Photomicrograph of core acidized

PRESENT TRENDS IN STUDIES OF THE MICHIGAN HURONIAN

ROBERT M. DICKEY

THE student of pre-Cambrian geology, somewhat bewildered ordinarily by an intricate mass of detail and a variety of conflicting opinions, occasionally finds value in attempts to summarize his information and to discern the general lines along which researches in the subject are proceeding. This is very true of investigations of the Michigan Huronian rocks, and an effort of this nature is highly appropriate during the centennial of the Michigan Geological Survey, which has participated ably and honorably in furthering the growth of knowledge of the pre-Cambrian geology of the state.

If, following Leith,[1] we regard the Algonkian as "that part of the pre-Cambrian sedimentary column in a particular region to which ordinary stratigraphic methods can be applied," the Huronian rocks of Michigan may be defined as that portion of the Algonkian which is at present stratigraphically delimited at its base by the Eparchean Interval and which has its upper stratigraphic terminus in the marked erosional break that preceded the deposition of the clastic beds of the Lower Keweenawan. The Michigan Huronian proper is, in generally accepted present usage, separated into the Lower, Middle, and Upper divisions by means of two well-marked and widespread unconformities which, although not characterized in many places by highly pronounced structural discordances, are nevertheless to our knowledge omnipresent in the known pre-Cambrian of the Upper Peninsula.

Since the Archean of Michigan, stratigraphically below the Algonkian, is defined by Leith [2] as "the underlying, more or less indivisible, basement complex, containing igneous or sedimentary rocks, or both, in which ordinary stratigraphic methods do not apply," the base of the Algonkian and that of the Huronian coincide in the

[1] Leith, C. K., "The Pre-Cambrian," *Proc. Geol. Soc. Am. for 1933*, p. 171. 1934.

[2] *Ibid.*

Eparchean Interval. By definition, however, this boundary is inherently one of temporary location, existing in its present position only until further detailed work and improved field and laboratory methods serve to decipher the riddles of the Archean and to depress the upper limit of the "indivisible" basement complex. Refinements in methods of study and mapping will doubtless clarify stratigraphic relationships which now seem to be almost hopelessly confused.

A deserved criticism of the present definitions of Archean and Algonkian may be based upon their lack of elasticity and upon their potential failure to answer future requirements. For example, a pre-Huronian sequence consisting largely of flows, which, because of lack of detailed study or by reason of its advanced metamorphism, has not been worked out in the past, may some day be unraveled. In such an event it must, if the present terminology is retained, exist as a unit left dangling between the Archean and the Algonkian, unable to enter the former division because no longer a portion of the indivisible basement complex or the latter because not dominantly sedimentary.

The term "Huronian" as employed in its modern sense carries no connotation of age equivalence of similar rocks in separated areas, but refers rather to rock type. Although not lending itself readily to definition in a few words, "Huronian type" includes pre-Cambrian rock sequences which are susceptible of treatment by ordinary stratigraphic methods and which are largely sedimentary, including both clastics and products of chemical precipitation, with subordinate amounts of pyroclastics and volcanics, all of which have been indurated by processes normal to an anamorphic environment.

If, then, "Huronian" is employed as a term descriptive of rock type, doubt may be expressed as to the future utility of the designations Lower, Middle, and Upper Huronian, since these obviously have reference to stratigraphic location. If, for instance, further investigation reveals, as it well may, the existence of a sequence of Huronian type unconformably below the base of our present Lower Huronian, will this sequence be regarded as Lower Huronian, and if so, how then shall we refer to our present Lower and Middle Huronian? Another possible danger attaching to the traditional separation of the Huronian into Lower, Middle, and Upper divisions is that reluctance will doubtless be felt to recognize any additional

major stratigraphic sequence which may be found as our knowledge of the Huronian rocks advances. In the present absence of such contingencies the existing nomenclature of the Huronian divisions answers our needs, but the future should witness no hesitancy in casting it aside in favor of a less rigid system of terminology as the occasion warrants.

The increasing acceptance of what may be referred to as the "type" classification of the pre-Cambrian rocks seems desirable and promises to remove many of the difficulties and controversies introduced into the study by premature attempts to set up in various correlations time equivalents based upon evidence which is all too often entirely insufficient.

"Archean" and "Algonkian" are almost universally employed to designate the major divisions of the pre-Cambrian by workers in that field in North America. Paleontologists and students of post-Lipalian stratigraphy are of similar unanimity in referring to these as "Archeozoic" and "Proterozoic." It is generally felt by geologists who deal largely with the pre-Cambrian that the latter terms carry with them implications of the existence of various forms of pre-Cambrian life which, upon the evidence afforded by the pre-Cambrian rocks, cannot be supported by a sound basis of fact. It is understandable that the paleontologist, viewing the abrupt appearance of manifold and varied life at the base of the Cambrian, should logically assume the existence of living forms in the pre-Cambrian. In the Lower Huronian Kona and Randville dolomites of the Upper Peninsula occur peculiar structures which have been regarded as algal in origin, and the writer inclines toward this view. These structures, because of their uniform condition of alternating broad convexities and sharp concavities upward, have been used for a number of years in determining the tops of complexly deformed beds in which they occur. However, many geologists familiar with the occurrences take issue with any ascription of organic origin to these features. These are perhaps the best direct evidences of the existence of life in the Michigan Huronian which have yet been discovered. Other evidence, of an indirect nature, is to be found in the presence of limestone in the Huronian and in the graphite of certain Huronian slates. In the Archean rocks of Michigan no traces of the existence of life have been discovered. Consequently, the student of the Michigan pre-Cambrian feels, doubtless with justification, that the burden

of proof in the form of conclusive field evidence rests with those who advocate a division of the pre-Cambrian upon a basis of the life supposed to have been present. Until such proof is brought forward, it is not unreasonable to state that the terms "Archean" and "Algonkian," which imply nothing as to life forms in the pre-Cambrian, are preferable to "Archeozoic" and "Proterozoic."

The broader outlines of the stratigraphy and of the correlation of the various members of the Michigan Huronian have been established, and in a number of instances, notably in the iron formations of the various ore-producing districts of Michigan, the stratigraphy has been covered in detail. Similar careful work has been done on various other divisions of the Huronian. Some of the results have been published, but a large part of the present information is unavailable in printed form. A great deal remains to be done in researches of this nature, and such efforts are of the utmost importance. Detailed studies of the iron formations, because of their obvious economic value, have progressed more rapidly and have received better financial support than projects dealing with other portions of the Huronian, where prospects of immediate monetary returns from an investment in such work are more uncertain.

In the correct deciphering of the stratigraphic minutiae of the Michigan Huronian rest our principal hopes of a proper understanding of the manner in which these rocks have reacted to deforming stresses. The writer ventures the prediction that, as progress is made in such investigations, faulting will be recognized as having played a much more important part in determining the present location and attitude of the Huronian beds than has generally been conceded in the past. It is not impossible that further discoveries of iron ore will be made similar to that of the great Plymouth open pit mine on the Gogebic Range, located in a downfaulted block of the Ironwood iron formation in an area where for many years only Archean rocks were believed to exist. Work directed toward this end should, needless to say, include not only the iron formations, but all rocks of the Huronian.

From a more or less academic standpoint relationships within the Huronian, and in particular the relationships of these rocks to the igneous complexes which bound them in many places, once understood, should yield valuable information upon the ultimate nature of deformation of the earth's crust. Perhaps nowhere can the deep-

seated conditions involved in mountain building be studied to better advantage than in the truncated, eroded roots of ancient mountain ranges now represented by the Huronian rocks of the Upper Peninsula. Attacks upon such problems are now being made, and although at present there is considerable lack of agreement in many instances upon the relative ages of the igneous rocks and the Huronian involved, a reconciliation of opposing views is doubtless not many years removed.

In stratigraphic studies of the Huronian the investigation of heavy accessory mineral assemblages occurring in the various rocks is attaining increasing prominence as an aid in correlation and in the understanding of the paleogeography and geologic history of the pre-Cambrian of the Upper Peninsula. The groundwork for this important phase of geologic activity is now being established by examination of hundreds of specimens from the Michigan pre-Cambrian, principally by S. A. Tyler and R. W. Marsden of the University of Wisconsin, and their results will soon be forthcoming. The subject is so broad as to provide an extremely interesting and almost inexhaustible field for future work. Not only will the prosecution of such endeavors add to our knowledge of the Huronian, but the study of heavy accessory mineral assemblages itself will undoubtedly benefit thereby, through improvements in technique and increasing standardization in methods.

Measurements of the absolute age of various igneous rocks of the pre-Cambrian by investigation of the products of radioactive disintegration are showing steady advances through the studies of A. C. Lane and W. D. Urry. Although many geologists are not at present disposed to accept their results as indisputable criteria in disagreements concerning correlation, such studies have even now, with the work in what might be termed its infancy, very definite value. To cite only a single case, for a number of years most of the basic dioritic dikes that cut the iron formation of the Gogebic Range have been regarded as Middle Keweenawan, and as having served in the capacity of feeders for the Middle Keweenawan traps. However, although definite evidence has not yet been uncovered, the conviction has been growing for some time that many of these dikes are pre-Keweenawan, and probably late Upper Huronian. This conviction has been supported by the results of age determination on a radioactive basis carried out by Lane and Urry, who used the helium method. Their

findings placed a specimen from one of these dikes as late Upper Huronian. Since the dikes bottom a large number of the Gogebic Range iron ore bodies, and have evidently exerted a definite influence upon the development of such ores, the correct determination of their relative age is of no small importance in studying the manner of concentration of the Ironwood iron formation to ore.

Leith [3] has deplored attempts to emphasize the time element in pre-Cambrian correlation, asserting, with reason, that our information is so meager as to render almost valueless correlations which stress this factor. He states, however, that in the future the time element may be validly introduced as researches progress which involve age determinations by studies of the products of radioactive disintegration, the proper correlation of separated batholiths, investigation of the heavy accessory mineral assemblages not only of pre-Cambrian igneous bodies but of pre-Cambrian sediments, the manner of origin of the pre-Cambrian iron formations, more extensive and detailed mapping of pre-Cambrian areas, and a study of metamorphic processes. This list may be amplified by mentioning the possibility of increasing future emphasis upon time planes represented by various deposits of volcanic ash, such as those of Hemlock and Clarksburg ages. The occurrences and implications of these have been studied for a number of years by W. A. Seaman. It is true that utilization of the various bentonite and metabentonite beds of the Paleozoic in this manner has not as yet met with widespread acceptance, but the potential significance of occurrences of volcanic ash within the Michigan Huronian should doubtless receive more general recognition than has been the case in the past. Further, our attempts to introduce the time factor into pre-Cambrian correlations encounter the same obstacles often met with in similar efforts elsewhere in the geologic column; the present knowledge of conditions of sedimentation is frequently inadequate to enable us to set up proper time relations among lithologically diverse portions of a given bed. In many instances our understanding of the time element in pre-Cambrian correlation will doubtless advance in step with increases in the steadily growing fund of information concerning the facts of sedimentation.

The problem of the origin of the Huronian iron formations of Michigan has been and continues to be a subject of much discussion.

[3] *Op. cit.*, pp. 169–172.

The unusual lithology of these rocks and the peculiar circumstance of their confinement in the geologic column to the pre-Cambrian, although they are of widespread geographic occurrence, furnish some basis for the suspicion that they are exceptions to the general validity of uniformitarianism in pre-Cambrian petrogenesis. A number of reasonable objections may be offered to either of the principal hypotheses of origin, i.e. that the iron formations are normal products of advanced weathering, and subaqueous transportation and deposition, or that they have been developed by precipitation of materials contributed to sea waters by submarine basic lavas. Rhythmic chemical precipitation of ferrous carbonate in gelatinous silica may have been a factor in producing their characteristic banded textures, but objections to this postulate can be readily interposed. Without detailed discussion of the various postulates of origin, it will perhaps suffice to mention here that students of the Huronian generally doubt that the final solution to the problem has been reached. No specific, intensive study of the question is being undertaken at present, apparently, but it is confidently expected that before many years elapse this outstanding challenge to geologic thought will be satisfactorily met.

More agreement exists regarding the manner of concentration of the iron formations to ore than the mode of origin of the iron formations proper, but opinion remains divided despite years of diligent effort directed to the subject. The majority of students familiar with the conditions believe that the iron ore concentration has been effected through the agency of oxidizing waters possessing an important downward component of movement, concentrated in their flow downward along favorable avenues of migration such as cross faults, and in the direction of pitch of structural troughs bottomed by impervious rocks of various types. Whether these waters were meteoric, hydrothermal, or hybrid remains a debated subject, and the scope of this paper does not permit full consideration of the several hypotheses. The preponderance of field evidence may be stated to favor meteoric water circulation as the dominant factor, but it is possible that this postulate does not cover the whole story. It is subject to constant critical inspection by all geologists interested in development of the Lake Superior iron ores.

The character of the deep mine waters in the Michigan Huronian has received little concerted attention since the studies of Lane. Al-

though a number of chemical analyses are available, many more should be made, and these should be carefully coördinated with the geology and the ore occurrences in the iron mines. The writer's work, now in progress, on the origin of the manganiferous iron ores of a portion of the Gogebic Range has led to the suspicion that deep mine waters, of the calcium chloride type, have been and are at present a factor in the transportation and deposition of manganese. The general subject of the origin, nature, and flow of these deep saline waters offers a promising field for future research.

It has been the aim of this paper to sketch the directions in which present-day thought on problems of the Michigan Huronian is trending and to point out a few potential fields for study. In the past decade geologists who have concerned themselves with the pre-Cambrian of Michigan have been relatively few, in part because of lack of financial support, and in some measure at least because the attention of Michigan geologists has been directed elsewhere. The opportunities existing in the Upper Peninsula for advancement of geological knowledge are magnificent; we have as yet made only a beginning. The problems of the pre-Cambrian are in general not essentially different from many of those existing throughout the geologic column, and pre-Cambrian work is not unique in its possession of structural and petrologic complexities. If the experience of many geologists who have dealt largely with more recent units of the geologic section could be brought to bear upon the intricacies of the Archean and the Algonkian, it can hardly be doubted that the progress of pre-Cambrian studies would be materially accelerated.

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THE ORIGIN OF PERCHED DUNES ON THE MANISTEE MORAINE, MICHIGAN

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INTRODUCTION

MANY of the sand dunes of northern Lake Michigan are perched in that they rest upon substrata elevated above the present lake level. The term "perched" includes dune forms resting upon old beaches referable to past glacial and postglacial lake stages, such as the Nipissing and the Algonquin. Dunes of this type on the Beaver Islands and on South Fox Island have been described by Fuller.[1] The present study, however, is concerned only with the perched dunes found along the western edges of the Manistee moraine, where the irregular spurs come out to the shore. This moraine constitutes the major portion of the second or inner ridge of the Port Huron morainic system (Fig. 1). Observations made thus far include Sleeping Bear Point and the shore line from Pointe Betsie south through Arcadia (Fig. 2). The primary purpose has been to determine if possible the chief origin of the sandy materials of which these perched dunes are composed. To this end an arbitrary classification into four main types was made:

Type I, Sand of beach origin — accumulation due to wind action.
Type II, Sand of beach origin — accumulation due to wind action accompanied by shore recession.
Type III, Sand derived from morainic drift.
Type IV, Sand of combined beach and morainic origin.

It should perhaps be mentioned that some geologists [2] believe that, immediately after the retreat of the ice and before vegetation had established itself upon the surface of the drift, the wind was peculiarly effective in forming loess deposits and sand dunes. The observations

[1] Fuller, George D., "Some Perched Dunes of Northern Lake Michigan and Their Vegetation," *Trans. Illinois State Acad. Sci.*, 11 : 112–115. 1918.

[2] See, for example, Sauer, C. O., "Geography of the Upper Illinois Valley and History of Development," *Illinois State Geol. Surv., Bull. 27*, p. 116. 1916.

of Russell [3] on the Malaspina Glacier were contradictory to this view. Here he found vegetation following closely upon the retreat of the ice, and even noted a dense forest growing on a moraine which rested upon the ice of the glacier. Though Russell was dealing in Alaska with a relatively local mountain glacier, whereas the ice

Fig. 1. The Manistee moraine (after Leverett). Dark areas indicate principal locations and close correlatives of the moraine

which covered the State of Michigan was of continental proportions, it does not seem as if the conditions attendant on the growth of vegetation would be vastly different. In any case, there seems to be little of practical value to be gained by introducing this theory into the solution of the present problem.

[3] Russell, Israel C., *Glaciers of North America*, pp. 113–114. 1897.

TYPE I: SAND OF BEACH ORIGIN — ACCUMULATION DUE TO WIND ACTION

There are two kinds of perched sand deposits of beach origin. Type I consists of sand which has blown up from the beach to the top of the moraine. In this type the height to which sand particles can be blown must be considered. The opinion of Barrows [4] that "winds can carry sand to any height up gentle slopes, but are unable to carry it up very steep slopes" seems generally to be favored. The truncated bluffs of the Manistee moraine range from a few feet to more than three hundred feet above Lake Michigan, with the angle of the front slope averaging approximately 53°. The angle of repose for sand is from 30° to 35°. The upper surface of the moraine is very irregular, and if the sand should be blown up the face of the bluff one would expect it to collect mainly in the hollows or along the lower portions. This condition is often true, but has not been found to be sufficiently consistent to serve as a determining factor.

Outcroppings of a pinkish clay, varying greatly in thickness, occur throughout the lower portions of the bluffs along this part of the shore. It is often laminated and is practically free from pebbles. The origin of this clay deposit, which was noted by Desor,[5] has been the subject of much speculation. The various theories cannot be treated here except to say that they indicate a widespread deposit, of earlier date than the surface morainal drift, but resting upon older glacial deposits. Leverett [6] believes the clay to have been laid down in a large body of water either during an ice recession within the Wisconsin stage of glaciation or as a pre-Wisconsin interglacial deposit.

Vegetation is able to gain a foothold more readily on the lower flanks of the bluffs mainly because the clay has a greater capability for retaining moisture than has the overlying drift material. The result is a zone of denser vegetation giving a distinctly banded

[4] Barrows, Harlan H., "Geography of the Middle Illinois Valley," *Illinois State Geol. Surv., Bull. 15*, p. 53. 1910.

[5] Desor, E., "On the Superficial Deposits of the District." In *Report on the Geology of the Lake Superior Land District*, by J. W. Foster and J. D. Whitney, Part II (Washington, 1851), p. 240.

[6] Leverett, Frank, and Taylor, Frank B., "The Pleistocene of Indiana and Michigan and the History of the Great Lakes," *U. S. Geol. Surv., Mon. 53*, pp. 314–315. 1915.

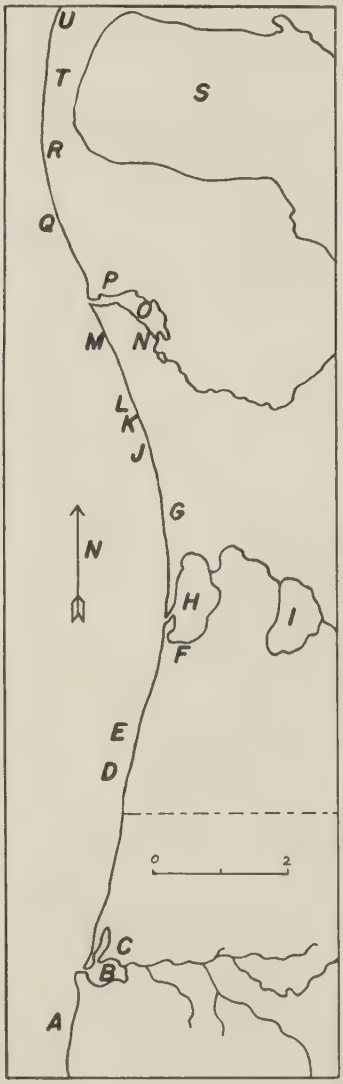

Fig. 2. Sketch map of shore line from Pointe Betsie south through Arcadia

A. First large perched dune south of Arcadia
B. North Bar Lake
C. Arcadia
D. "Baldy"
E. "Razor Back"
F. Watervale
G. "Lookout Hill"
H. Lower Herring Lake
I. Upper Herring Lake
J. Large blowout
K. Low spot in moraine
L. Low morainic hill
M. "Thelma's Cradle"
N. Elberta
O. Lake Betsie
P. Frankfort
Q. "Crater" group
R. Wildewood Resort
S. Crystal Lake
T. Crystal Lake bar
U. Pointe Betsie Light

appearance to the surface of the slope (Pl. I, Fig. 1). If sand were blown from the beach, up the slope, it would be retarded and trapped by this vegetation. Along the lower portions of the bluffs, however, there seldom seems to be much loose sand on the surface. A possible exception to this observation may exist near "Razor Back" (*E* [7]). Here an inclined coating of fine sand leading from the beach up to a height of about fifty feet seems to indicate transportation up the slope.

On the edge of the bluff at Sleeping Bear Point, Glen Arbor Township, one can almost always feel the sting from rather coarse particles of sand being carried and blown inland by the wind. It is difficult to determine whether or not this sand comes directly up the slope. Along the southern portion of the bluff may be found scattered tufts of grass, behind each of which is a small accumulation of sand, which would seemingly indicate progression of the sand up the face of the bluff in a northeasterly direction. Of course, with a northwest wind, sand could readily blow up the more gentle slope out at the end of the point and continue south along the front face of the bluff until, with a shift of the wind to the west, it would migrate directly inland. This, however, does not seem to occur. It is probable, therefore, that some of the sand does progress directly up the bluff from the beach below, but *slowly*.

To quote from Free,[8] "It has become apparent that much surface material is moved from place to place by aeolian action and that much of this transport is to be ascribed to the slow and unnoticed, but continuous, action of ordinary winds. The winds are so ubiquitous and so incessantly in motion that their aggregate geologic work is by no means negligible, though it may be momentarily inappreciable." This seems to be true of the area under consideration, and in all likelihood some of the sand incorporated in the perched dunes is material that, over a long period of time, has progressed slowly up the steep slopes of the moraine.

TYPE II: SAND OF BEACH ORIGIN — ACCUMULATION DUE TO WIND ACTION ACCOMPANIED BY SHORE RECESSION

Type II consists of sand which has been forced to migrate from the beach inland and up the slopes of the moraine as the shore line

[7] Capital letters refer to locations on the outline map, Figure 2.

[8] Free, E. E., "A Possible Error in the Estimates of the Rate of Geologic Denudation," *Science*, N. S., pp. 423–424. 1909.

has been cut back by the waves. That the dunes are formed by this second method is the most common explanation of perched sand deposits. Solger [9] gives a good illustration of this mode of formation on the adjusted coast of Pomerania. Whether or not this explanation holds true in the Lake Michigan region is somewhat doubtful. For one thing, the lakeward slopes of the moraine are, and must also in the past have been, far steeper than those up which the dunes in Pomerania have traveled. This is true of all the portions of the moraine studied, with the exception of the section extending south from Elberta past "Thelma's Cradle" (*M*) and the area in the vicinity of the extremely low spot in the moraine (*K*), for at these places the height of the moraine is not so great. There seems to be no reason why the sand could not have moved up onto the moraine as the shore was cut back and this may well have occurred at *M*. At *L*, however, there is a slight rise in the surface of the moraine in the form of a gently rolling hill elongated in an east west direction. The western extremity of this hill has been only partly truncated, and, if the theory were correct, one would expect to find sand in the process of migrating up the still rather gentle slope. There is, however, only a very slight windblown deposit along the edge, far too small to be classed as a dune. Thus it would seem that, with the possible exception of the example cited above, formation of perched dunes by this method is unimportant in this area, although it must not be neglected as a contributing factor.

TYPE III: SAND DERIVED FROM MORAINIC DRIFT

Sand supplied by this third method could be derived either from the drift exposed by erosion on the face of the bluff or from surface deflation of the sandy till. In the following discussion it will be apparent that surface deflation is of relatively small importance, for the action ceases to be effective as soon as the larger residual particles are sufficiently numerous to protect the surface.

As has been stated, layers of pink clay are common in the lower parts of the moraine. On top of this clay morainic drift has been deposited in varying amounts. There are, furthermore, many local differences in the character of the materials composing the drift. It is common, especially in the upper portions of the moraine, for layers of fine sand to alternate in every possible way with layers of

[9] Solger, F., *Dünenbuch*, p. 98, fig. 28. 1910.

pebbles. In many places this imperfectly stratified material appears to be a water-laid deposit. Some of it probably represents local débris reworked and redeposited by the waters resulting from the melting of the ice. In any event, the upper portions, even when there is a liberal admixture of pebbles, are predominantly sandy.

Leverett's[10] soil studies for the townships in Benzie County which are situated nearest the Lake Michigan shore between Crystal Lake and Manistee County show that of 33 sections, 12 are swamp and lake, 4 are mostly sand, and 17 are sandy till. The same general composition occurs in Leelanau County, Glen Arbor Township, where, of 20 sections, the distribution is 6, 4, and 10, respectively.

Because of the extremely sandy drift in the exposed bluffs many of the early geologists mistakenly considered them wind-blown deposits. This was especially true of Sleeping Bear Point, which Schoolcraft,[11] in 1820, called "a bank of sand 200 feet high and 8 or 9 miles long." The same error appeared repeatedly on maps,[12] and as late as 1851 Desor [13] thought the bluffs nothing but a huge dune, although he rightly recognized the sandy deposits near the Manistee River as being of glacial origin.

In the present study an effort has been made to determine whether or not the perched dunes are better developed opposite local exposures of unusually sandy material than elsewhere. Results obtained have not been conclusive thus far, but a more important factor than such a location appears to be the action of gullying in the normally sandy drift. Frequently this gullying and sliding has been intense, and perched deposits of sand seem to occur in greater quantity at the heads of the gullies. This is especially characteristic of the bluff south from the low spot in the moraine (*K*) and also south of "Baldy" (*D*). There is much loose material and, often, fine sand in the gullies. In all instances noted this appears to be sliding down from the top of the bluff toward the beach below.

Except for a sparse natural growth which obtains a precarious

[10] Leverett, Frank, "Surface Geology and Agricultural Conditions of the Southern Peninsula of Michigan," *Ann. Rep. Mich. Geol. and Biol. Surv.*, Publ. 9, Series 7, pp. 93, 114. 1911.

[11] Schoolcraft, H. R., *Narrative Journal of Travels through the Northwestern Regions of the United States to the Sources of the Mississippi River in 1820*, p. 401. 1821.

[12] Young, J. H., *The Tourist's Pocket Map of Michigan.* Philadelphia: S. A. Mitchell, 1837.

[13] Desor, E., p. 263 of work cited in note 5.

foothold, what vegetation exists on the upper portions of these bluffs is mainly of the "slip slope" type (Pl. I, Fig. 2). Often trees along the edges of the bluffs are undercut and expose a tangled mass of dried roots. Trees, shrubs, and larger plant forms on the slope usually have slipped down from above. These slowly die or continue their gradual descent to the base of the bluff, where they are destroyed by the waves at periods of high water.

As erosion of the bluff progresses the upper portions retreat consistently. Fresh material is constantly exposed, and as it breaks off or slumps down from the edge the larger and coarser fragments which are too big to be carried readily by the wind begin to slide down the slope. The rapidity of their descent depends upon their size and shape and upon local conditions. One can always find at the base of the bluff near "Razor Back" (*E*) and also at a place south of "Baldy" (*D*) beautifully striated and polished boulders which have been loosened by erosion and have rolled down the slope from above. That these boulders have been exposed recently is indicated by the high lustrous polish found on some of them. This polish could not have been retained if they had been directly subjected to weathering processes for even a relatively short time. Occasionally, however, angular fragments of softer rock remain on the slope sufficiently long to become pitted and blasted. Stone lattice effects are often produced on a minor scale. These corrugations indicate, further, that the wind must be carrying an appreciable quantity of sand, and that a certain amount of finer material must constantly blow up, or blow around, on the slope.

It is thought that, as the coarser pieces begin their descent of the slope, the finer fragments or sandy particles with which they have been associated are picked up or rolled along by the wind and are carried up over the edge of the bluff and deposited on top of the moraine. This is considered to be true mainly of the finer materials exposed in the upper portions of the slope, where they can easily be carried the short distance to the summit.

When sand particles reach the top of the bluff their progress may be checked somewhat by vegetal covering on the upper surface. Such growth usually consists of a dense tangle of wild grape, poison ivy, bittersweet, and associated xerophytic types. Here the sand collects and eventually becomes heaped up in a narrow perched ridge paralleling the edge of the slope. With continued erosion and under-

mining of the bluff it is not long before the lakeward part of this perched ridge slumps. The fine sand is picked up by the wind and blown to the top again, and the process is repeated. Examples of this type of narrow perched dune along the edge of the bluff are very common. (See the rough sketch of the "Crater" group, Fig. 3.)

An interesting sand deposit, closely allied to this border type of perched dune, is found at *A*, south of Arcadia. On the summit of the bluff a layer of sand, eight or more feet thick, is being blown inland. Between this capping layer of sand and the edge of the bluff a bench, four or five feet in width, shows the original very sandy and slightly pebbly surface of the moraine. On this bench stands a row of dead pine trees (Pl. II, Fig. 1). From all appearances, the sandy capping layer has advanced not only into, but through, the onetime forest fringe. A few of the dead trees have fallen from their position and have rolled down the slope. The bluff is apparently being cut back rather rapidly. However, as it is eroded, the loose capping sand is moved more easily by the wind than is the material on which the trees were formerly growing. This old surface, though very sandy, is probably almost entirely morainic and is therefore somewhat more consolidated and less readily shifted. Also, the dead tree roots may still exert some binding influence on this old layer. It seems as though the loose sand on top must originally have been derived from the old sandy morainic surface when the bluff extended farther to the west. With the erosion of the slope this sandy material has been blown up and inland, so that at present there are two distinct sandy horizons, the top one consisting mainly of a redeposition farther inland of the particles in the bottom layer.

FIG. 3. The "Crater" group, an example of the border type of perched dune in southern Michigan

Where vegetation does not check the sand movement, or where other conditions are favorable, the sand may be blown inland to form larger perched dunes and apices. These eventually become deformed as constant recession of the bluff truncates the lakeward portions, and the process may result in the formation of large blow-

outs or "horseshoes." Inland migration is also facilitated by the addition of fresh sand to the perched dunes. This addition takes place as the fine drift material continues to be exposed in the upper parts of the eroded face of the bluff.

When the sand has been blown inland for some distance, into large horseshoes, there may be a broad opening at the lakeward end, or the entrance may consist of a narrow wind rift between high arms of sand (Pl. II, Fig. 2). In either case the opening is usually practically devoid of vegetation, and deflation has progressed to such an extent that most of the finer material has been removed. The coarser materials originally present in the upper portions of the drift are thus left as an imperfect pavement on the surface. Although this coarse layer is a quite effective preventive of surface erosion by the wind, it affords only temporary protection to the moraine and is not proof against undermining along the edge of the bluff. As has been shown, this latter action is most important.

At various places the surface of the moraine exposed seems to dip down sharply to the east, so that the perched sands rest on the eastern flanks of partly eroded swells in the moraine and may fill basin-like hollows or sags. Eventually, in many locations, the height of the moraine will be somewhat reduced as erosion of the front slope continues back into these hollows (Pl. II, Fig. 2; Pl. III, Fig. 1).

As a result of the constant erosion of the lakeward parts of the Manistee moraine much fine material does exist on the front surfaces of the bluffs. Under favorable conditions this loose sand may be picked up by the wind, and some of it may eventually reach the top of the slope to add to the perched accumulation. On several occasions sand movement along the slopes was noted. In one instance the bluff south of "Razor Back" (*E*) was observed when a high wind was coming from the southwest. A small amount of sand seemed to be blowing up from the beach onto the lower flanks of the moraine. The most apparent movement, however, was on the slopes themselves, where the sand was blowing northward, in a course horizontal to the face of the bluff. In places where the sandy drift jutted out the cliffs were "smoking." Most of the material being moved seemed to come from the sandy patches on the slopes themselves, and the particles were being carried along without much apparent change in elevation.

Needless to say, all the fine material exposed near the top of the bluff is not blown up the slope. Much of it undoubtedly slides down along with the coarser fragments. During heavy storms, slides and flows of finer material often occur. Also, when great sections held together by tree and plant roots break off from the top of the bluff both coarse and fine materials are carried down the slope.

The rate at which this process takes place depends entirely upon the rapidity of erosion of the bluffs, and the erosion, though unceasing, varies in intensity with the location. Minor factors must also be taken into consideration. If vegetation is able to gain a foothold temporarily, erosion is retarded. Again, during periods when the level of Lake Michigan is unusually high, as it was in the summer of 1929, the waves cut directly into the bases of the bluffs and greatly accelerate the erosive process.

Because of the irregularity of the moraine it is impossible to estimate how much material has been removed, but the amount must have been very great. However, Leverett[14] believes that southward from Frankfort the nearness of deep water to the present shore precludes the supposition that the headlands were as long as those farther north. This factor would also militate against formation of dunes of the second type. The Crystal Lake bar was formed during Algonquin time[15] and is unusual because at present it has a convex curvature toward the Lake Michigan shore. It is thought that it developed originally as a normal bar of concave outline between the limiting morainic ridges, and that subsequent erosion cut back the land and reversed the curvature of the bar. Thus it may be seen that erosion, since Algonquin time, has been intense at this particular point along the shore.

That erosion of the sandy drift material is probably of great significance in the accumulation of sand on top of the moraine is borne out at location *K*, south of Frankfort. This site appears to furnish one of the important keys to the solution of the problem. Here, as compared with the height of the bluffs on either side, there is a relatively low spot in the moraine. The total elevation from the beach to the top of the bluff is about 66 feet, and the reddish sandy clay outcrops up to approximately 49.5 feet. There is a thin

[14] P. 427 of work cited in note 6.

[15] Scott, Irving D., "Inland Lakes of Michigan," *Ann. Rep. Mich. Geol. and Biol. Surv. 1920*, Publ. 30, Geol. Series 25, p. 172. 1921.

recent sand deposit on the upper surface. This leaves only 10 feet of morainic drift overlying the clay, an amount much less than that normally found. Although this low spot is apparently particularly favorable for such action, sand does not seem to be blown up from the beach, nor is there any accumulation due to migration up the slope as the shore has receded. On the other hand, this is the only locality where the overlying sandy drift is noticeably much thinner and where there would be a deficiency in the supply of sand exposed by erosion.

From all evidences, therefore, sandy material derived from the morainic drift would seem to be the most important constituent of the perched dunes in the areas described.

To review briefly, erosion of the drift along the edge of the bluff results in a natural sorting action, and in the removal of the larger particles. The sandy accumulation which remains, bordering as it does the edge of the slope, is in a constant state of simultaneous accretion and destruction. This unstable condition persists until such time as the sand may be picked up by the wind and transported inland, out of immediate danger from undermining.

TYPE IV: SAND OF COMBINED BEACH AND MORAINIC ORIGIN

Studies made thus far indicate that the majority of the perched dunes of the Manistee moraine belong to the fourth, or composite, type.

The amounts of sand derived from the three types included under this composite grouping vary, but, as a rule, the second type is unimportant, the first type is responsible for a moderate percentage of the material, and the third type is the dominant contributing factor.

In conclusion, it is believed that a brief description of Sleeping Bear Point may be of interest, since it presents somewhat different conditions than ordinarily exist in other parts of the area studied. Here splendid examples of *Windkanten* can be found in the rocky capping layer. Because of its exposed location the entire surface of the moraine, bordering the lake, has been swept bare of most of the fine sandy material, with the exception of the perched relic or remnant known as the "Bear" and another small sandy accumulation to the south. The "Bear," which is the most prominent perched feature, is a rather small hill whose front slopes extend down to the top edge

of the bluff (Pl. III, Fig. 1). Exhumed trees and old humus layers indicate that it was not all built at one period, but is composed of sand blown up from various directions at different times. The main part of the hill appears to have been at one time slightly more to the south and west. At present the base of the northern slope is covered mainly with arborvitae, and a dense growth of calamovilfa, sand cherry, and dogwood occurs nearer the top. The back, or eastern, slope is thickly wooded in patches, the intervening areas being grassed (Pl. III, Fig. 2). The southern and western slopes are being actively eroded, and it is evident that a large amount of material has recently been removed, for a great difference was noted between the appearance of this portion of the dune in 1934 and in 1936, two years later. Waterman [16] in his article on the ecology of this area also mentions the rapid erosion of the "Bear." Indeed it is surprising that such an exposed and unstable remnant should have persisted over so long a period. It was well known to the Indians who formerly inhabited the area, and was frequently made the subject of their legendary tales.

The vast semiperched accumulation of moving sand steadily advancing eastward toward Glen Lake is composed almost wholly of material swept from the exposed surfaces of the higher portions of the moraine. The edge of the moraine is notched by a series of gullies oriented for the most part northeast southwest. The larger gullies represent intermittent drainage channels. They branch slightly and cut deeply into the moraine. The northern slope of each is covered with loose stones, but fresh sand covers the stones on the southern slope. Extending northeast on the top of the moraine from the southern flank of each gully is a long, narrow tail of sand, varying in size with the size of the gully. This material appears to come from sandy outcroppings some distance down the face of the bluff.

CONCLUSIONS

An attempt has been made in the present study to determine what processes have been most effective in the development of the perched sand dunes found on the Manistee moraine along the eastern shore of northern Lake Michigan.

1. It is believed that, over a long period of time, sand blown up

[16] Waterman, Warren G., "Ecology of Glen Lake and Sleeping Bear Region," *Pap. Mich. Acad. Sci., Arts, and Letters*, 6 (1926) : 363. 1927.

from the beach to the top of the moraine has contributed a considerable amount of material to the perched dunes.

2. In this area actual migration of the dunes up the morainic slopes, with continued recession of the shore line, does not seem to have been important.

3. It is thought that the greater part of the material in the dunes has been derived from the sandy drift of the moraine. In this process continual erosion of the front slope of the bluff and effective wind action have played an important part.

4. The perched dunes are termed composite, since their origin can be ascribed to no single factor or process, but seems to include in varying degrees all the types noted above.

Further studies of the perched dunes in other portions of the Manistee moraine will have to be made before these observations can be completely verified.

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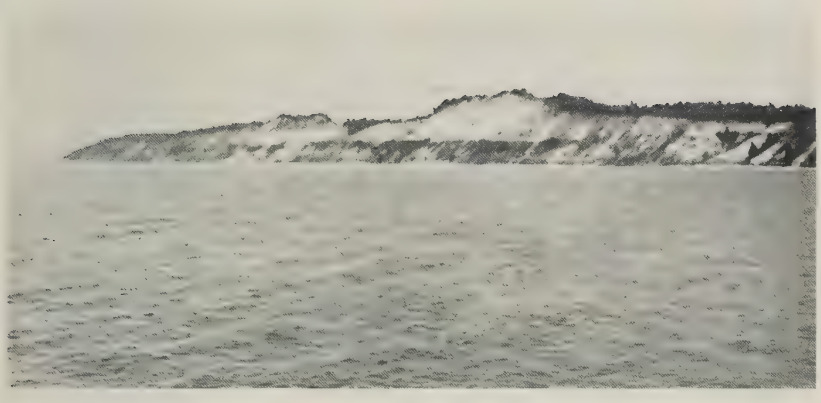

FIG. 1. Shore line north of Frankfort opposite "Crater" group, showing denser vegetation on clay in lower parts of bluff

FIG. 2. Bluff near "Razor Back," showing typical sandy drift and slip-slope vegetation. Note undermining along edge of bluff in upper right-hand corner; also steepness and height of slope

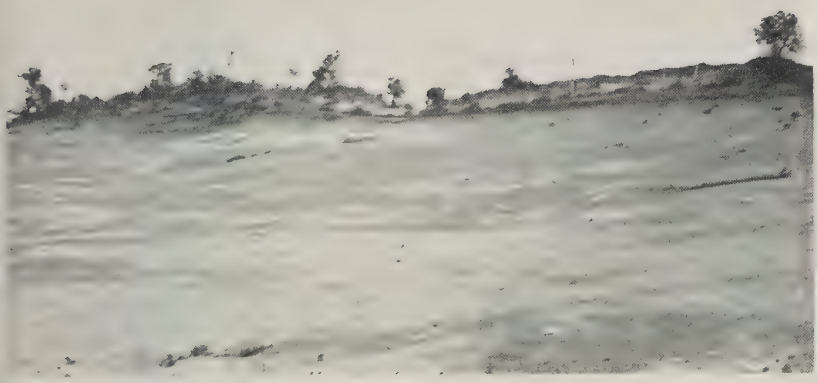

FIG. 1. Bluff south of Arcadia, showing how sandy capping layer has migrated into and through former forest fringe

FIG. 2. Descending from "Baldy." View looking west toward Lake Michigan through wind rift. Note high area of sand on either side and manner in which surface of moraine rises toward edge of bluff

FIG. 1. "Sleeping Bear." View looking north; South Manitou Island in distance. Note particularly character of moraine and steepness of slope toward lake

FIG. 2. "Sleeping Bear." View looking west toward Lake Michigan. Note sand hummocks in foreground and higher surface of moraine to the west

THE ROGERS CITY LIMESTONE, A NEW MIDDLE DEVONIAN FORMATION IN MICHIGAN

GEORGE M. EHLERS AND ROBERT E. RADABAUGH

DURING 1922 the senior author of this paper had occasion to examine a few gastropods which were collected from the so-called Dundee limestone of Presque Isle County, Michigan, by the late Mr. H. H. Hindshaw of Alpena, Michigan. As a result of this examination two of the specimens were found to be identical with *Büchelia tyrrelli* (Whiteaves) and *Omphalocirrus manitobensis* Whiteaves, species which occur in the Middle Devonian strata of Manitoba.

The senior author did not have an opportunity to determine the exact stratigraphic occurrence of these gastropods until the summer of 1926, at which time he participated in a preliminary study of the so-called Dundee limestone and the Traverse group of rocks for the Michigan Geological Survey. During the course of the 1926 study he found that the upper half of the "Dundee" limestone contained the two gastropods noted in the previous paragraph and several other fossils which were identical with or closely related to species occurring in the Manitoban limestone and the underlying Winnipegosan dolomite of Manitoba. This information was transmitted to Dr. E. R. Pohl, who noted (1930*a*, p. 31, and 1930*b*, p. 60) the presence of "Manitoba beds" with a northern fauna above the Dundee limestone.

During the summer of 1936 the writers of the present paper spent several days in a study of the "Dundee" limestone of Presque Isle County. As a result of this study they are able to recognize two formations in the "Dundee" limestone, a lower one, with a characteristic Dundee limestone fauna, to which the name "Dundee limestone" should be restricted, and an upper one, with a fauna distinct from that of the Dundee limestone, for which the name "Rogers City limestone" is proposed.

The best exposure of the Rogers City limestone is exhibited in the very large quarry of the Michigan Limestone and Chemical Company at Rogers City, Presque Isle County. The lithologic character and the common fossils of the Rogers City and Dundee limestones of this quarry are noted in the following generalized section.

SECTION OF STRATA EXPOSED IN QUARRY OF MICHIGAN LIMESTONE AND CHEMICAL COMPANY AT ROGERS CITY, MICHIGAN

	THICKNESS	
	Feet	*Inches*
Traverse group (Bell shale)		
9. Shale, calcareous, bluish gray and abundantly fossiliferous.	1–10	
Disconformity		
Rogers City limestone		
8. Limestone, buff-gray to buff, medium-grained, fairly thick-bedded and porous, containing *Prismatophyllum sp.*, *Favosites sp.*, a costellate *Atrypa*, *Büchelia tyrrelli* (Whiteaves), *Omphalocirrus manitobensis* Whiteaves, and other gastropods	49	
7. Limestone, gray, finely crystalline, dense and thick-bedded, containing numerous specimens of *Gypidula sp.*, a few individuals of a costellate *Atrypa*, and *Omphalocirrus manitobensis* Whiteaves	4–6	
6. Limestone. Lower 2 to 3 feet mottled buff and buff-gray, magnesian and thin-bedded; upper 6 feet less mottled, less magnesian and thicker-bedded than underlying beds. Limestone contains numerous specimens of a costellate *Atrypa*, a few specimens of *Gypidula sp.*, and *Omphalocirrus manitobensis* Whiteaves	8	6
5. Dolomite, with discontinuous, alternating buff and buff-gray bands, fine-grained and thin-bedded, with molds of *Productella sp.*, *Atrypa sp.* and other brachiopods, pelecypods, *Tentaculites sp.*, and *Proetus sp.*	8–9	
Dundee limestone		
4. Limestone, gray, weathering to a buff-gray, composed of numerous shells of brachiopods and a smaller number of other invertebrates. Characteristic fossils are *Prismatophyllum sp.*, *Productella spinulocostata* Hall, *Etheridgina? spinosa* Bassett, *Atrypa costata* Bassett, *A. ehlersi* Bassett, *Spirifer lucasensis* Stauffer, and a species of *Athyris* identical with a species found in Dundee limestone of southeastern Michigan	6	5
3. Limestone, gray, weathering buff-gray, with few chert nodules and remains of *Prismatophyllum sp.*, *Atrypa costata* Bassett, *A. ehlersi* Bassett, and other fossils	2–3	

2. Limestone, buff-gray to buff, weathering to brown, and thick-bedded, with *Diphyphyllum rectiseptatum* Rominger, *Prismatophyllum sp.* with corallites averaging 8 mm. in diameter, *Prismatophyllum sp.* with corallites 4 to 5 mm. in diameter, *Atrypa costata* Bassett, and *A. ehlersi* Bassett 59

1. Limestone, buff-gray to gray, mottled, dense and somewhat magnesian in lower part, containing *Synaptophyllum? sp.*, *Atrypa elegans* Grabau, *A. costata* Bassett, *Pentamerella sp.* cf. *P. parva* Bassett, and numerous specimens of *Paracyclas sp.* 72

In the description of this section the Dundee limestone is shown to have a thickness of 139 to 140 feet; the Rogers City limestone, 69½ to 72½ feet; and the Bell shale, 1 to 10 feet. The maximum thicknesses of these three formations in near-by areas are greater, however, than those exhibited in the quarry.

Drilling tests made by the Michigan Limestone and Chemical Company show that dolomites and some limestones are present beneath the lowest Dundee strata exposed in the quarry. Further information may indicate that a part of these dolomites and limestones belong to the Dundee formation and a part to the underlying Mackinac limestone, which appears at the surface in the region bordering the Strait of Mackinac.

The maximum thickness of the Rogers City limestone, as shown by diamond drill cores a few miles south of the quarry, is about 106 feet; that of the Bell shale is about 60 feet.

From the foregoing discussion the Rogers City limestone of the type section exhibited in the Michigan Limestone and Chemical Company quarry at Rogers City may be defined as the strata occupying a position between the Dundee limestone and the Bell shale of the Traverse group.

The base of the Rogers City limestone apparently is conformable with the Dundee limestone and, where it appears in the Michigan Limestone and Chemical Company quarry, is at the base of a conspicuous 8- to 9-foot bed of dolomite (see Pl. I, Figs. 1–2). More extensive field work may indicate that the contact is not conformable; furthermore, study of large collections of fossils from the dolomite may prove that this bed should be included within the underlying Dundee limestone.

The contact of the Rogers City limestone with the overlying Bell shale is disconformable; the effects of erosion of the Rogers City

limestone prior to the deposition of the Bell shale are well illustrated. In the quarry of the Michigan Limestone and Chemical Company, about two miles south of the crusher plant, the Bell shale occupies a broad, shallow depression eroded in the Rogers City limestone. Beneath the bottom of the depression the Rogers City limestone is only about 60 feet in thickness, which, when compared with the maximum thickness of 106 feet, indicates a local removal of 46 feet of strata. The surface of the limestone in this depression shows anastomosing solution channels, one to two inches in width and averaging about one inch in depth, which were formed by weathering prior to the deposition of the Bell shale (see Pl. II, Fig. 1). During the course of quarrying so-called pockets of Bell shale are encountered within the Rogers City limestone. Some of these pockets are small caverns formed by the solution of the limestone prior to the deposition of the shale and subsequently filled with it (see Pl. II, Fig. 2); others are crevices formed by solution along joints and later filled with the shale.

The stratigraphic relationship of the Rogers City limestone to the Devonian section of New York is of considerable interest. The limestone is overlain by the Bell shale, which probably is a correlate of some part of the Hamilton group of New York below the Ludlowville formation. It is underlain by the Dundee limestone, which occupies a stratigraphic position at some unknown distance above limestone breccias with overlying calcareous strata collectively known as the Mackinac limestone and exposed in the region bordering the Strait of Mackinac. On Mackinac Island just east of the strait are cherty limestones which, as noted by Dr. Carl Rominger (1873, pp. 24 26), contain numerous typical Onondaga fossils, some of which are present in the underlying breccias. Since the upper part and possibly all of the Mackinac limestone is of Onondaga age, as shown by the studies of Rominger and of Grabau (1913, p. 365), the Dundee and the Rogers City limestones are seen to hold a position in the standard New York Devonian section between the Ulsterian and the Erian series, which contain respectively the Onondaga limestone and the Hamilton group, the correlatives of the Mackinac limestone and Traverse group. Whether the Dundee and the Rogers City limestones should be assigned to the Ulsterian or the Erian series or to a distinct series can be determined only by further study.

The Rogers City limestone is related to certain Devonian strata of northwestern Manitoba, which, according to Dr. E. M. Kindle

(1914, pp. 248, 251 257), consist of the Elm Point limestone at the base, the Winnipegosan dolomite in the middle, and the Manitoban limestone at the top. A large number of species of gastropods and a few species of other invertebrates, which were listed by J. B. Tyrrell (1892, pp. 207–208 E) as being confined to the Winnipegosan dolomite, have been found in the Rogers City limestone. *Stringocephalus burtini* Defrance, which is characteristic of the Winnipegosan dolomite and certain Middle Devonian strata of Europe, has not been found in the Rogers City limestone. The apparent absence of *Stringocephalus* in the Rogers City limestone seems unusual, because this limestone contains many gastropod genera which are characteristic of the *Stringocephalus* zone of Manitoba and Europe. Some of the genera and species of gastropods found in the Rogers City limestone have been reported from both the Stringocephalus-bearing Winnipegosan dolomite and the Manitoban limestone. The occurrence of these genera and species in the Winnipegosan dolomite and the Manitoban limestone makes it impossible at this time to state whether one or both of these formations should be correlated with the Rogers City limestone. It is hoped that a further study of these formations and their faunas by the junior author will show the exact stratigraphic relationship of the Rogers City limestone to the Devonian strata of Manitoba.

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FIG. 1. Part of southern face of Michigan Limestone and Chemical Company quarry at Rogers City, showing contact between Dundee and Rogers City limestones. Light band just above contact represents the conspicuous dolomite described as interval 5 of the quarry section (see p. 442)

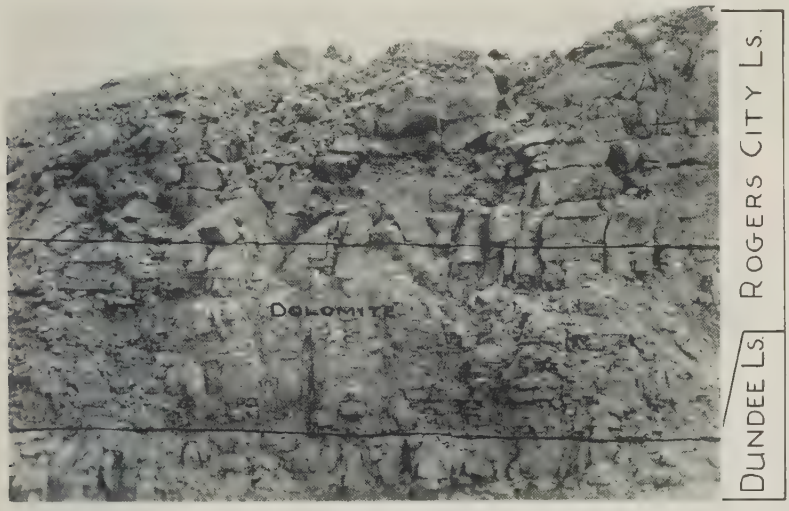

FIG. 2. Northern face of same quarry, showing in detail the contact between the Dundee and Rogers City limestones and the thin bedding of the dolomite just above this contact

FIG. 1. Upper surface of a block of Rogers City limestone, showing anastomosing channels formed by solution prior to deposition of Bell shale. Note presence of Bell shale, shown by lighter color, in many of the channels

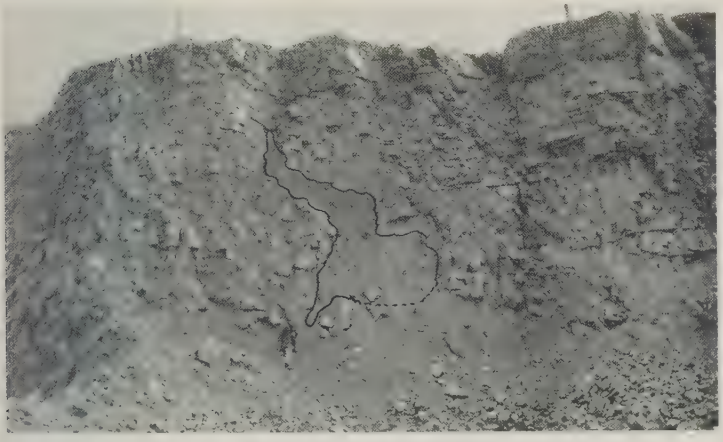

FIG. 2. Mass of Bell shale in a small cavern (outlined in ink at center) within the Rogers City limestone of the Michigan Limestone and Chemical Company quarry

LITHOLOGY OF THE TRAVERSE GROUP OF CENTRAL MICHIGAN

BENJAMIN F. HAKE AND JED B. MAEBIUS

SCOPE OF PAPER

IN THIS paper it is the writers' intention to delineate and describe briefly the character and extent of the lithologic units into which they have been able to subdivide the Traverse group in central Michigan, where these rocks are at considerable depths beneath the surface and are known only from samples obtained by drilling. They also wish to suggest possible correlations between the lithologic units of the Traverse group as determined by subsurface methods and the formations into which the group has been divided by those who have studied surface exposures. Because of the impossibility of examining the strata directly, the Traverse group in central Michigan can never be satisfactorily subdivided on a faunal basis.

The divisions of the Traverse group here made are essentially divisions of expediency, but experience has shown that these lithologic units are capable of precise recognition over short distances and of approximate identification for distances of many miles, in some instances almost completely across the state. These divisions are thus formations, at least in the sense of being units capable of identification over large areas, and they may prove to be of greater service than many of the formations to which names have been applied.

NATURE OF PREPARATORY WORK

The data here presented are derived wholly from examination of samples taken from wells drilled for oil. These samples were collected systematically as the drilling progressed, successive samples representing thicknesses of strata ranging between 2 and 20 feet. Before examination the samples were thoroughly washed; on account of the elimination of mud from the cuttings, it is possible that during the examination of samples some thin beds of shale may

have been penetrated by the wells without being recognized. The authors do not believe that this possibility represents any great actual loss because it is their observation that, where limestones are interbedded with any noticeable amount of shale, the limestones are themselves slightly argillaceous. Furthermore, considerable experience in subsurface geological work has convinced the senior author that, if any important part of a geologic section is composed of shale, some quantities of that material remain in the samples after repeated washings, even where those shales are composed to a large extent of very soft or even absorbent clays.

The samples are subjected to systematic megascopic and microscopic examination, and also to some investigation by treatment with acid and staining fluids to bring into relief the textures and mineralogical compositions of the rock chips. The collection of data for this report has been carried on over a period of about two and one-half years, during which time samples of the Traverse group from many scores of wells have been examined. The descriptions presented on the cross sections are from wells selected chiefly on account of the completeness and the authenticity of their sample record (see Appendix). All descriptions and statements made in this paper concerning the rocks of this group refer solely to the characteristics of the sediments within the area traversed by the accompanying sections, since the writers have had but little opportunity to visit or to study the surface exposures of these rocks.

ACKNOWLEDGMENTS

For opportunity to make and permission to publish the observations reported here the writers are indebted to the Gulf Refining Company. They also wish to acknowledge the assistance of Mrs. Helen Cannon, who, while working as assistant to the senior author, contributed to this paper by examining many of the sets of samples used. Dr. G. M. Ehlers has been very generous with his time and his intimate knowledge of surface exposures of the group in helping with the formulation of a tentative correlation between the divisions here made and those recognizable in the outcrop. Many oil companies, drilling contractors, and individual operators have rendered valuable aid by preserving samples of these formations where penetrated by their wells. Samples collected by the Department of Conservation have also been of great assistance.

SEDIMENTS UNDERLYING THE TRAVERSE GROUP

The Traverse group is underlain by massive calcareous sediments which are generally spoken of as Dundee, but which in many localities may actually be of greater age. In the eastern part of the state the Traverse rests on a brown dense to fine-grained limestone which is correlated with the Dundee formation. In the central part the lithology of this underlying series is quite variable, being in some places pure limestone like that in eastern Michigan and in others dolomitic limestone. In some localities pure dolomites occur. In Isabella and Gratiot counties and southwestward it is doubtful in many places whether the Traverse rests on Dundee or on some older beds. Farther west, in the vicinity of Kent and Muskegon counties, the Traverse rests on buff to brown, dense to fine-grained limestone which is similar to and tentatively correlated with the Dundee formation.

The beds beneath the Traverse are remarkably free from argillaceous material. Recognizable fossil fragments are very rare. The beds are brown to buff, locally almost white. The gray color, which is predominant in the Traverse, is lacking in the sediments below it.

THE TRAVERSE BASIN OF SUBSIDENCE

In its major aspects the depression within which the Traverse formation was deposited is an elongated basin, with its principal axis in a northwest–southeast position and situated approximately beneath the inner portion of Saginaw Bay (Fig. 1). The maximum observed depth of this basin occurs northwest of the north shore of Saginaw Bay, but it cannot be stated that this is the greatest depth of the basin because there has not yet been enough drilling along the apparent northwest prolongation of the axis to define the area of maximum subsidence.

The regional warping by which this basin of deposition was produced was complicated to some extent by localized crustal deformations, as is evidenced by considerable variations in the total thickness of the Traverse group displayed by closely adjacent wells. On account of the fact that so many of the wells have been completed without preserving adequate samples of the Traverse, it has been impossible to formulate any worth-while conclusions concerning the details of diastrophism in Michigan during Traverse time.

GENERAL CHARACTERISTICS OF THE TRAVERSE SEDIMENTS

Though recognizing that such procedure may prove to be incorrect, the writers use the term "Traverse group" in this paper to designate that series of beds which underlies all gray and black shales near the base of the Antrim formation and which overlies the massive, buff to brown, relatively unfossiliferous limestones and dolomites belonging to the Dundee and older formations.

The predominant feature of the lithology of the Traverse group of sediments in central Michigan is its composition of calcareous, argillaceous, and siliceous materials in various degrees of admixture. These rocks range from remarkably pure limestones through cherty, dolomitic, and shaly limestones and limy shales to nearly pure clay shales.

Limestones and dolomites predominate in the west and southwest. In southern Ottawa and northern Allegan counties the Traverse group is composed entirely of massive clean limestone and dolomite. Beds of shale appear in the group a few miles north and east, and these intercalated shales increase in number and thickness eastward across the state, so that in north-central Huron County massive limestone composes only about 20 per cent of the thickness of the group.

Although brown limestones and white limestones occur frequently, the characteristic color of this group is gray. This appearance is due in part to the fact that many of the limestones are made up of comminuted fragments of fossils of different shades and textures and in part to the presence of varying amounts of clay.

The second outstanding characteristic of the rocks of this group is the presence of abundant fossil débris, which includes fragments of corals, hydrozoans, bryozoans, crinoids, and brachiopods. In many localities and at several stratigraphic horizons wells penetrated long sequences of even-textured light-colored limestone without notable evidence of stratification and with a minimum of recognizable fragments of such fossils as brachiopods and crinoids. These are regarded as fossil reefs composed of the remains of hydrozoans, corals, and algae.

Chert is abundant in many of the purer limestones and has been noted in a few places where the rocks are quite argillaceous. A few individual samples are composed almost entirely of chert, showing

the presence of lentils of dense, massive chert up to 10 feet in thickness. In most occurrences, however, the chert is intimately intergrown with the limestone, and sometimes to such a degree as to require chemical or petrographic methods for distinction between the minerals.

Dolomitic limestones are fairly common in the Traverse group; in some localities such rocks compose the bulk of the section. The lithology of these dolomitic sediments varies from a dense to fine-grained calcitic limestone enclosing minute rhombohedral crystals of dolomite, through beds which appear to be composed of limestone strata with lentils of dolomite, to pure granular holocrystalline dolomites.

Observed lithology of the Traverse group and the subdivisions herein recognized as units are shown by the sections presented in the accompanying figures.

DESCRIPTION OF LITHOLOGIC UNITS

Bell Shale

The lowest unit of the Traverse group is composed of gray shales which are only slightly calcareous, except in their basal portion, which is characterized by the presence of pyrite and an abundance of crinoids and ostracods. In the central part of the state, especially in Montcalm County, there is at the contact a black organic dolomite which contains abundant pyrite and which may belong either to the Traverse group or to the underlying series. The thickness of this bed varies from 2 to 15 feet. Beds associated with this basal member frequently yield specimens of a finely ribbed brachiopod so small that they are sometimes undamaged by the drill.

The beds above this contact zone are gray, slightly calcareous shales with only a few fossil fragments. The maximum observed thickness of the Bell shale is 110 feet in Manistee County (Fig. 3). It is nearly as thick over a considerable area, being 80 feet thick in Antrim County (Fig. 4), 75 in the Saginaw Bay region, and 70 in Alpena County (Fig. 2). The Bell shale thins southwestward from the center of the state until in Muskegon County it is only 5 feet thick. It disappears entirely in Allegan County and has not been observed farther southwestward.

In the lowest 10 to 20 feet of the Bell shale in Montcalm County (No. 8, Fig. 2) there occurs a bed of brown granular dolomitic lime-

stone very similar to the so-called Dundee of that region. In the drilling of several wells this bed has been erroneously called Dundee until subsequent deepening revealed the error.

The samples from one well in Manistee County indicate that there is a 5-foot bed of shale carrying large quantities of anhydrite about 25 feet below the top of the Bell. However, since similar occurrences have not been recognized in other wells and since anhydrite beds were exposed in the open hole above this point while drilling was in progress, the authenticity of this one is open to question.

Rockport Limestone

Above the Bell shale there is a variable thickness of beds more calcareous than those either above or below it. In the northeastern part of the state this unit is a relatively pure limestone (Fig. 2) and is probably approximately equivalent to the beds exposed in the Rockport quarry.[1] It is generally highly fossiliferous and locally cherty. In most of its occurrences it contains so much shale that it is our custom to describe it as a limy shale. In many sets of samples it is represented only by a notable abundance of calcareous fossils.

To the southwest this unit loses its identity because of the increasing lime content of the overlying beds, and southwest of Lake and Montcalm counties (Figs. 2–3) the writers have not been able definitely to recognize any equivalent for it. To the northwest, in Roscommon and Antrim counties (Fig. 4), there is a 60- to 80-foot thickness of relatively pure, fossiliferous, locally dolomitic gray limestone near the base of the Traverse section, which is correlated with the Rockport.

The writers have been unable to recognize the Rockport in samples from wells in northern Shiawassee County, where the relationships between the logs (Nos. 33–35, Fig. 4) suggest that the Traverse loses thickness by progressive southward overlap.

Middle Shale and Limestone Unit

Above the Rockport there is a series of shales, limy shales, muddy limestones, cherty limestones, and dolomites which attains a maximum thickness of about 220 feet (Figs. 2, 4) in the region surround-

[1] Smith, R. A., "Limestones of Michigan," *Mich. Geol. and Biol. Survey*, Publ. 21, Geol. Ser. 17, p. 174 (1916).

ing Saginaw Bay. It thins to 190 feet in Alpena County and is not over 120 feet thick in Livingston County. It is characterized by the presence of gray shales with a varying lime content interbedded with varying thicknesses of limestone. The majority of the interbedded limestones are brown to black; they contain less chert than the limestones of the higher members of the Traverse group.

This unit in Alpena County is believed to contain the equivalents of the Long Lake stage of Grabau,[2] which includes the Ferron Point, Genshaw, and Killians of Warthin and Cooper.[3] A black limestone, probably equivalent to Warthin and Cooper's Killians limestone, is recognized as the upper of two heavy limestones in the logs of wells No. 17 and No. 18 in Alcona and Alpena counties (Fig. 2). Comparison of the logs of some of the wells in the central part of the state suggests that this middle shale and limestone unit contains large lenticular bodies of limestone (Fig. 2), which are usually dark brown and highly organic but which are locally black like the Killians.

The identity of this unit is lost in the western part of the state, where it seems to have been replaced by massive limestone and dolomite. Whether this was accomplished by change of facies in contemporaneous sediments or by overlap cannot be determined definitely at present. The authors are inclined to favor the idea of lateral gradation from shales and limestones to massive limestone.

To the south this member seems to be disappearing by overlap, but in northern Lenawee County well No. 36 (Fig. 4) drilled 70 feet of limy shale enclosing 10 feet of dense limestone, which is regarded as belonging to this unit. This shale is probably also equivalent in part to the Silica shale of Ohio.[4]

Middle Massive Limestone Unit

The most prominent lithologic unit of the Traverse group is composed almost wholly of massive limestones and dolomites with varying large amounts of chert. In an eastward direction the limestone is displaced by intercalated shales to such an extent that in northern Huron County the apparent stratigraphic position of this

[2] Grabau, A. W., "Stratigraphy of the Traverse Group of Michigan," *Geol. Surv. Mich., Ann. Rept. for 1901*, pp. 163–210. 1902.

[3] Warthin, A. S., Jr., and Cooper, G. A., "New Formation Names in the Michigan Devonian," *Journ. Wash. Acad. Sci.*, Vol. 25, No. 12. 1935.

[4] Stewart, Grace A., "Ostracods of the Silica Shale, Middle Devonian of Ohio," *Journ. Geol.*, 16 : 739. 1936.

limestone member is occupied by shales, with a few relatively thin beds of cherty limestone.

In the central part of the state, where the identity of this unit is fairly well established over a considerable area (Fig. 2), its thickness ranges between 250 and 300 feet. The majority of the limestones are light gray to white, and appear to be composed principally of fossil remains. Corals, brachiopods, crinoids, and bryozoans are especially abundant throughout.

Chert occurs in varying amounts from top to bottom of this unit, some beds being almost pure. It is sometimes dense and massive, which suggests the presence of large lentils or heavy beds, but often it is so intimately intergrown with the limestone as to render its detection difficult. In color it varies from light brown through shades of gray to pure white. The cherty zones are capable of fairly accurate correlation over distances of from 6 to 10 miles.

The writers have been unable to subdivide this unit satisfactorily into individual members or strata, because in a general way it is much alike throughout its thickness, and in minor characteristics it is extremely variable. In nearly every set of samples there occurs at least one and sometimes several thick zones of dense, even-textured, light-colored limestone, with only minor quantities of recognizable fossil material and most of that consisting of tiny fragments of corals. These sections, which are interpreted as reefs, constitute one of its principal characteristics.

Dolomitic limestones and dolomites occur in several positions in the unit and have been recognized in numerous localities throughout the state. In the central and eastern part dolomitic strata make up only a small fraction of its total thickness. One exception to this statement is well No. 14 (Fig. 2), in which it was found to be dolomitic through more than half of its thickness. The reason for such an occurrence gives rise to much interesting speculation, but so far no satisfactory explanation has been formulated. Dolomitic limestones are thicker and more frequent in the Traverse group in the southwestern part of the state. One or two sets of samples examined were found to be almost entirely pure dolomite.

In Muskegon County the upper portion of the lower half of the Traverse section contains a thick series of dolomites and anhydrites (Fig. 2). This member has not been positively identified outside Muskegon County, but similar sediments, in a similar stratigraphic

position, have been recognized in wells in several of the westernmost counties. A persistent dolomite, which may be partly equivalent to the member, has been observed in a number of wells in Kent County. In several sets of samples from Muskegon, Manistee, Antrim, Lake, Newaygo, Kent, and Montcalm counties dolomitic zones were noted in the upper part of the Traverse group. These may prove to be approximately contemporaneous, but their equivalence has not been definitely established. Like cherty zones, the dolomitic horizons are useful as markers for local stratigraphic and structural purposes within limited areas, but do not appear to be sufficiently uniform and continuous for regional correlations.

In the upper part of this unit there are porous zones that contain salt water and, locally, oil and gas. These porous zones do not seem to be confined to a single definite horizon, but are usually near the top of the highest chert.

Beds of shale are present within this predominantly limy unit, but they are not very prominent west of Gladwin and Saginaw counties. East and southeast of these counties shales increase so rapidly in number and thickness as to suggest that this entire series of cherty limestones must disappear somewhere under Lake Huron.

The logs of wells in Alcona and Alpena counties (Nos. 17–18, Fig. 2) indicate that what is here called the middle massive limestone unit of the Traverse group includes the Alpena limestone in its lower portion and probably among its upper members equivalents of the beds to which Warthin and Cooper [5] have applied the names Norway Point, Potter Farm, and Partridge Point (Thunder Bay stage of Grabau [6]).

The writers have been unable to make a satisfactory correlation between their subdivisions of the Traverse group and those of the Petoskey section as described by Pohl.[7] This is partly because the samples from the nearest well (No. 27, Fig. 4) were an imperfect set, and partly because Pohl's descriptions of rocks examined by him emphasize characteristics which are not easily recognized in well samples.

Fifty feet of massive limestone and cherty dolomitic limestone

[5] *Op. cit.* [6] *Op. cit.*

[7] Pohl, Erwin R., "The Middle Devonian Traverse Group of Rocks in Michigan: A Summary of Existing Knowledge," *Proc. U. S. Nat. Museum* 76, Art. 14, 1–34. 1929.

represents this middle massive limestone unit in well No. 36 (Fig. 4) in Lenawee County, and these limestones may be equivalent to the cherty limestones exposed on Ten Mile Creek in Ohio.[8]

Upper Shale Unit

Above the middle massive limestone unit there is a very persistent and rather uniform gray shale, which attains a maximum observed thickness of 90 feet in southern Arenac County (well No. 15, Fig. 2). From this region it thins to the west, south, and north, but information from the east is not available. The thinning of this shale unit from its area of maximum thickness takes place rather rapidly at first and then more slowly. In southern Saginaw County and in Gratiot, Isabella, Clare, and Roscommon counties this unit is not over 40 feet thick. It is recognizable in Lenawee County (well No. 36, Fig. 4), where it has a thickness of 35 feet, but it is absent on the Howell anticline in Livingston County (well No. 35, Fig. 4). Southwestward it is recognized as far as Kent County (well No. 4, Fig. 2), but it has not been identified westward beyond Isabella County (well No. 22, Fig. 3), nor has it been recognized in the extreme northwestern part of the state.

In most of the well sections this shale unit appears as a light gray shale, uniform in character and texture, and rather poor in fossil content. To the northeast it becomes more calcareous, and in Ogemaw (well No. 16, Fig. 2) and Huron counties it contains some intercalated beds of limestone.

No definite correlation has been made between this shale and formations described from surface exposures because well No. 18 (Fig. 2) started in what is believed to be the upper part of the Alpena limestone and well No. 17 (next nearest to the type localities) does not appear to have any section which can be definitely identified as the Partridge Point or Potter Farm of Warthin and Cooper,[9] although this shale is believed to occupy a stratigraphic position immediately below their Squaw Bay limestone.

Squaw Bay Limestone

The uppermost member of what is here included in the Traverse group is a fine-grained, light brown, usually dolomitic limestone. On

[8] Stauffer, C. R., "Middle Devonian of Ohio," *Geol. Surv. of Ohio, Bull. No. 10*, Fourth Series, pp. 145–146. 1909.

[9] *Op. cit.*

the basis of similarity of appearance and stratigraphic position this unit is correlated with the Squaw Bay limestone of Warthin and Cooper.[10] It has been recognized in well sections about as widely throughout the state as has any other unit of the Traverse group. Its thickness ranges from 15 to 40 feet, the variations appearing to be due to local conditions rather than to any systematic regional influences. It has been recognized in almost every set of samples seen by the writers from Huron and Alcona counties on the northeast, through Lenawee County on the south, Kent County on the southwest, Montcalm County to the west, and Roscommon County to the northwest. It has not been identified in Muskegon, Lake, or Antrim counties.

This unit is generally porous and salt-water bearing, and in some localities yields oil and gas. In the earlier times of oil development in Michigan it was spoken of as the "Saginaw sand."

Overlying Transition Zone

After the deposition of the Squaw Bay limestone there was sporadic and intermittent deposition of gray shales similar in character to those of the Traverse group. In some places also thin beds of gray limestone were deposited in association with these gray shales. These gray beds are interbedded with black shales typical of the Antrim formation. In the western part of the state a series of gray shale, with a few limy beds, rests on typical Traverse limestone and has been generally accepted by geologists as the uppermost member of the Traverse group. Eastward, however, these upper shales and limestones are found to be very discontinuous. Rocks in the corresponding stratigraphic position are chiefly black shales of the distinctive Antrim type, with one or several thin beds of gray shale of the Traverse type. Locally the gray sediments are entirely missing in samples from this horizon, which may be significant or may be due to poor sampling.

Because this zone does not constitute a definable lithologic unit and because it is largely composed of rocks which definitely are not of the Traverse type, it has here been excluded from the Traverse group and is recognized only as a transition phase between the Traverse group and the Antrim formation.

[10] *Op. cit.*

HISTORICAL GEOLOGY

Because of the fact that fossils are almost always broken into very small fragments before being recovered from wells the writers have believed that in all probability such fossil material as is available from well cuttings would be so imperfect as to prove of little use for purposes of correlation or faunal zoning. On that account and because of the necessity of logging a large number of wells in a limited time, they have done no systematic collecting of fossils during the progress of the sample examination. Some small collections were made from a few of the wells described in this paper, but the reports of paleontologists who undertook the examination of this material have not yet been received. In the absence of a knowledge of the distribution of individual faunas or of faunal affinities, the writers' notions of historical geology are necessarily based entirely on lithologic variations within the group.

Since much shale occurs in the lower and upper portions of this group, and the intervening strata are of nearly pure limestone, it appears to record the invasion of the area by a sea which spread so far beyond the limits of the state that little clastic material was delivered into central Michigan during a considerable part of Traverse time. Because the group as a whole contains increasing amounts of shale to the south, east, and northeast, it seems reasonable to conclude that the shores of this sea lay in those directions from central Michigan. The Traverse thins to the northeast and very rapidly to the south, and therefore it is reasoned that this sea probably advanced from the west and northwest and that any temporary regressions during the deposition of the Traverse group were probably toward the west and northwest.

The extent to which the terrain may have been subjected to subaërial erosion prior to inundation by the Traverse sea is a question which must be solved by a detailed study of the Dundee and older formations. The very gentle slopes displayed by the upper surface of the Dundee formation (if post-Marshall structural influences are neglected) indicate that this terrain was one of very low relief. The apparent absence of anything which could be termed a basal conglomerate at the contact between the Traverse and the rocks upon which it rests argues that the advance of the Traverse sea involved no considerable amount of wave cutting.

In the western part of the state the waters of the Traverse sea must have been remarkably clear throughout most of the period represented by the group, for in that part of the state the outstanding characteristic of the rocks of the Traverse group is the almost complete absence of clastic material. It may be that the reefs which are so abundant in the group prevented the transportation of much clastic material from the littoral zones into that part of the Traverse sea which covered what is now southwestern Michigan.

The repeated deposition of relatively pure limestone in the predominantly shaly lower part of the Traverse section in the more southerly and easterly parts of the state seems to record periods when the seas of this region were less muddy than usual. These periods of calcareous deposition may have been when the shores of the Traverse sea were temporarily at very low topographic relief or when climatic conditions were such as to produce but little erosion, or when the subsidence of the basin of deposition proceeded at a sufficient rate to produce relatively deep water.

The presence of anhydrites just below the middle of the Traverse section in Antrim County (Fig. 4) and the occurrence of a dolomitic zone in a similar stratigraphic position in Muskegon, Kent, and Montcalm counties (Fig. 2) suggest a time of concentration of the waters and possible separation of part of the Traverse sea from the oceanic waters of the time, perhaps by a system of barrier reefs.

A decrease in the area of the Traverse sea, or at least a decrease in the depth of its marginal waters, is recorded by the rather pure shales which overlie the Alpena limestone and constitute a wedge (Fig. 2) extending from the east into the central portion of the middle massive limestone unit of this report. It seems possible that this suggested contraction of the area may have been contemporaneous with the increased salinity which promoted the deposition of anhydrite in the upper part of the Traverse group in Antrim County (Fig. 4). It is perhaps a significant observation that a very persistent dolomitic zone occupies substantially the same stratigraphic position in southern and southeastern Michigan.

After Alpena time the Traverse sea may have been temporarily deprived of part or all of its connection with the open oceans of that time and this event may have been accompanied by a retreat of the littoral zone and a concentration of the waters of the Traverse sea, thus permitting the zone of shale deposition to ad-

vance toward the center of the basin and causing the deposition of anhydrites and dolomites or rocks which later became dolomites.

A subsequent period, when the Traverse sea was relatively shallow and mud-laden over a large part of Michigan, is recorded by the shale series which is here designated the upper shale unit. The return of clear-water conditions, presumably caused by further regional subsidence, is indicated by the purity of the Squaw Bay limestone.

The unit here called the overlying transition zone records the final withdrawal of the Traverse sea or the alteration of the paleogeography in such a manner as to cause cessation of the Traverse type of deposition in the area and inception of the deposition of the distinctive black organic shale of the Antrim formation.

Gulf Refining Company
Saginaw, Michigan

APPENDIX

WELLS USED IN SECTIONS OF TRAVERSE GROUP

1. Continental Gas & Oil Co.	No. 15	Walker	Sec. 26	10 N–16 W
2. Muskegon Oil Corp.	No. 1	Gasser	Sec. 27	10 N–15 W
3. Rex Oil & Gas Co.	No. 1	Johnson	Sec. 36	10 N–12 W
4. National Minerals Corp.	No. 1	Lewis	Sec. 5	10 N–11 W
5. Sidney Montcalm Oil Co.	No. 1	Madison	Sec. 33	10 N–7 W
6. Old Dutch Oil & Gas Co.	No. 1	Russell	Sec. 29	10 N–6 W
7. Ottolan Oil Corp.	No. 1	West & Benjamin	Sec. 17	10 N–5 W
8. Gulf Refining Co.	No. 1	Fisher	Sec. 2	10 N–5 W
9. J. G. Tiplady, Trustee	No. 1	Laycock	Sec. 11	11 N–3 W
10. H. E. Bell	No. 1	Nilsen	Sec. 16	13 N–3 W
11. Brehm-Hollman Oil Co.	No. 1	McBlain	Sec. 13	15 N–3 W
12. J. V. Wicklund	No. 1	Neal	Sec. 13	16 N–2 W
13. Goll, Graves & Mechling	No. 1	Oard	Sec. 25	18 N–1 W
14. Tamblyn & Martindale	No. 1	Buffalo Land Co.	Sec. 7	19 N–3 E
15. Melling Oil & Gas Co.	No. 1	Roma	Sec. 6	21 N–3 E
16. Richfield-Backus Oil Corp.	No. 1	Linton	Sec. 18	23 N–3 E
17. G. R. Thalman & J. A. Morris	No. 1	Kehlman	Sec. 10	26 N–7 E
18. C. W. Teater	No. 1	Nevins	Sec. 18	32 N–6 E
19. J. Bolema	No. 1	Red Wing Dev. Co.	Sec. 15	21 N–16 W
20. C. W. Teater	No. 1	McCabe	Sec. 26	20 N–12 W
21. Daily Crude Oil Co.	No. 1	Hoffman	Sec. 9	16 N–7 W
22. Pure Oil Co.	No. 1	McClintic	Sec. 15	14 N–6 W
23. Pure Oil Co.	No. 1	Bluemer	Sec. 10	12 N–1 E
24. W. R. Borough	No. 1	Brady & Fordney	Sec. 29	11 N–4 E

25. Mid-State Dev. Co.	No. 1	Burleson	Sec. 21	10 N–5 E
26. Smith Petroleum Co.	No. 1	Jolly	Sec. 5	9 N–8 E
27. McClanahan Oil Co.	No. 1	White-Pearson	Sec. 4	31 N 5 W
28. North Michigan Land & Oil Co.	No. 1	Hartwick	Sec. 31	24 N 4 W
29. Sun Oil Co.	No. 1	Becker	Sec. 2	18 N–3 W
30. M. F. Whitehill, Sr.	No. 1	Spicer	Sec. 11	17 N–2 W
31. H. L. McEvoy	No. 1	Glander	Sec. 18	14 N–3 E
32. A. H. Weber, Trustee	No. 1	Kirchner	Sec. 15	13 N 3 E
33. Smith Petroleum Co.	No. 1	Chase	Sec. 21	9 N 2 E
34. D. H. O'Donnell	No. 1	Hardy	Sec. 7	6 N–4 E
35. Talbot Oil Co.	No. 1	McPherson	Sec. 35	3 N–4 E
36. St. Louis Pipe & Supply Co.	No. 1	Dibble	Sec. 16	5 S–3 E

FIGURES 1–4

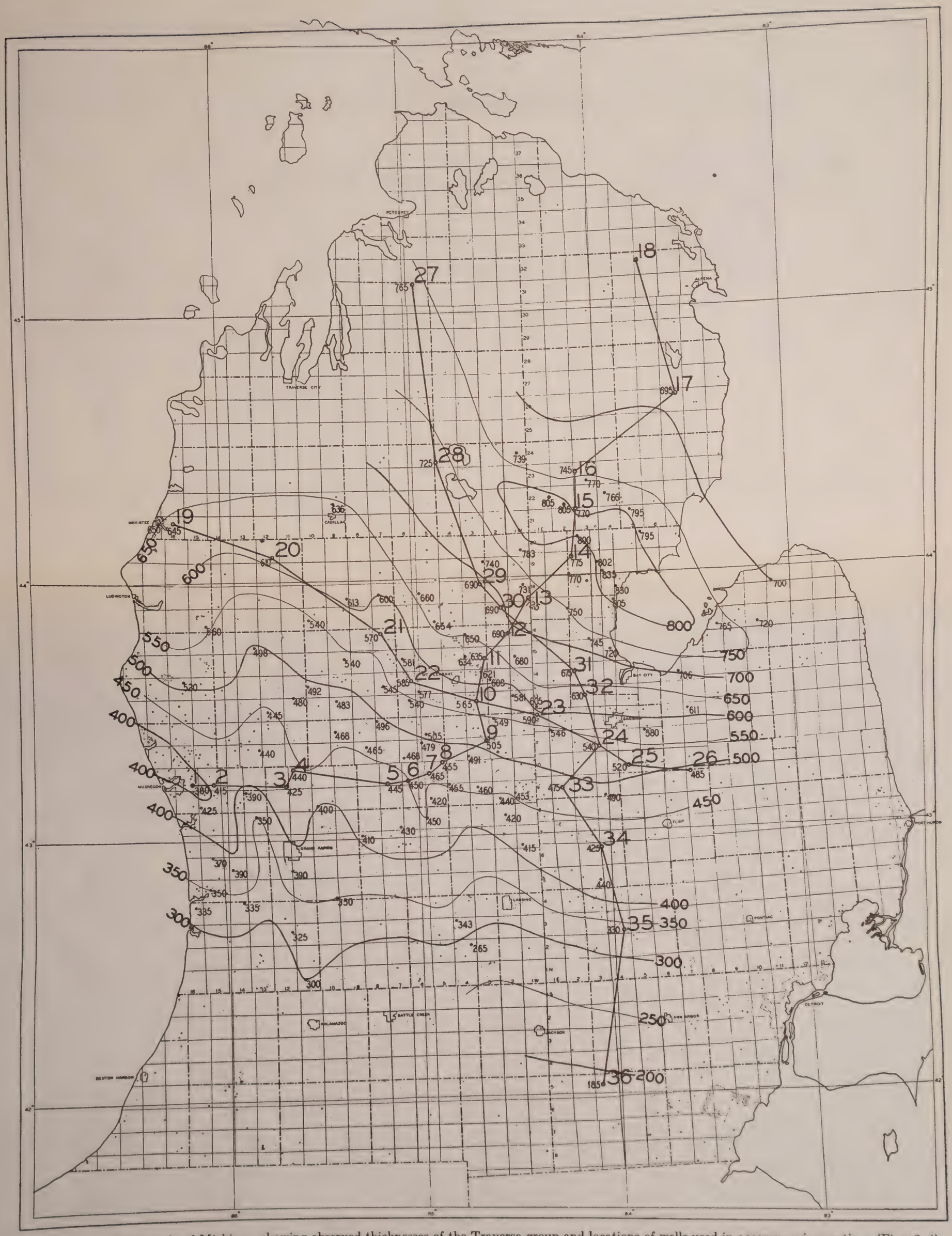

FIG. 1. Lower Peninsula of Michigan, showing observed thicknesses of the Traverse group and locations of wells used in accompanying sections (Figs. 2–4)

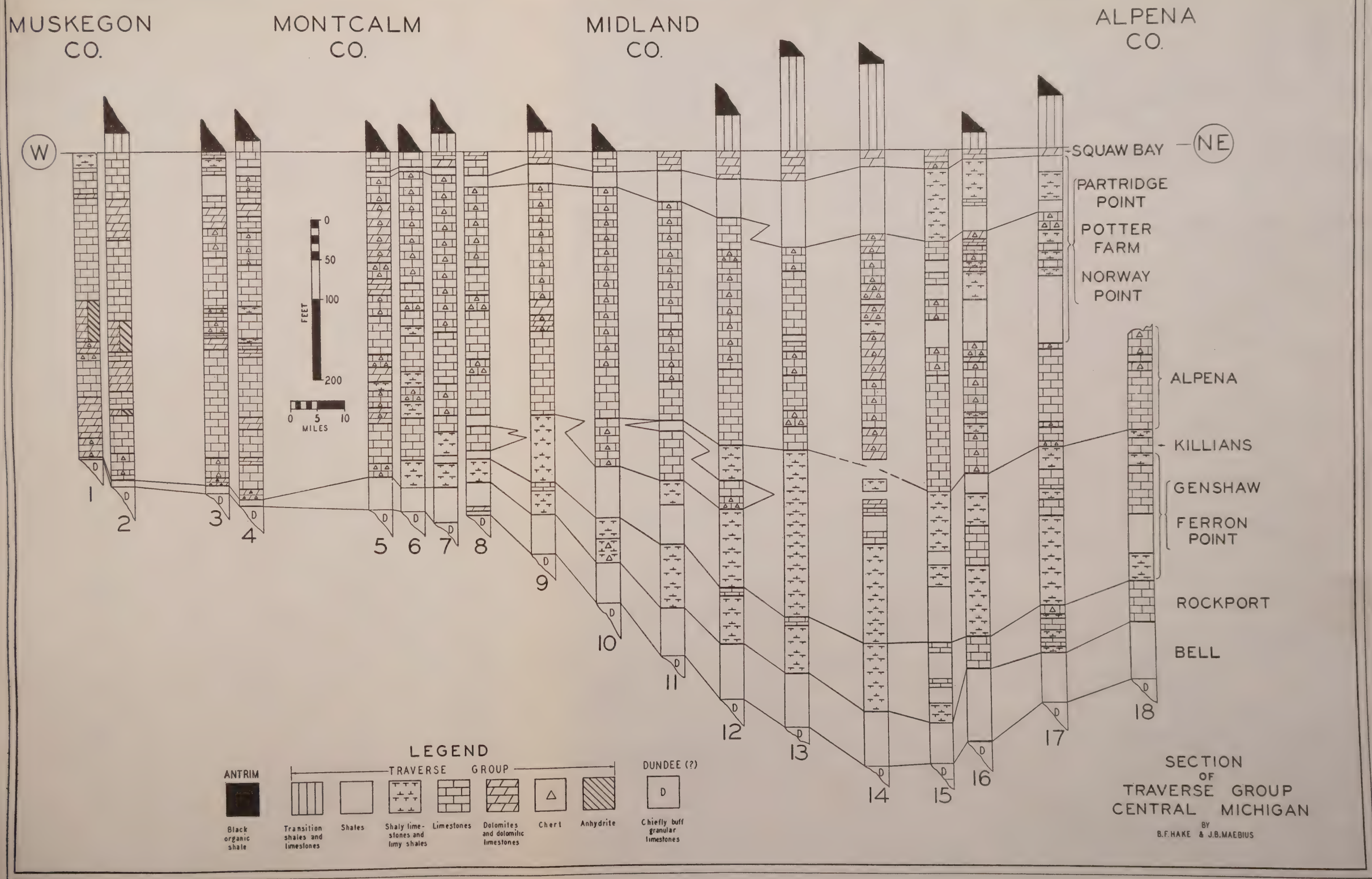
MUSKEGON CO.
MONTCALM CO.
MIDLAND CO.
ALPENA CO.
W
NE
SQUAW BAY
PARTRIDGE POINT
POTTER FARM
NORWAY POINT
ALPENA
KILLIANS
GENSHAW
FERRON POINT
ROCKPORT
BELL
0
50
100
200
FEET
0 5 10
MILES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
D
LEGEND
ANTRIM
TRAVERSE GROUP
DUNDEE (?)
Black organic shale
Transition shales and limestones
Shales
Shaly lime-stones and limy shales
Limestones
Dolomites and dolomitic limestones
Chert
Anhydrite
Chiefly buff granular limestones
SECTION OF TRAVERSE GROUP CENTRAL MICHIGAN
BY B.F.HAKE & J.B.MAEBIUS

FIG. 2

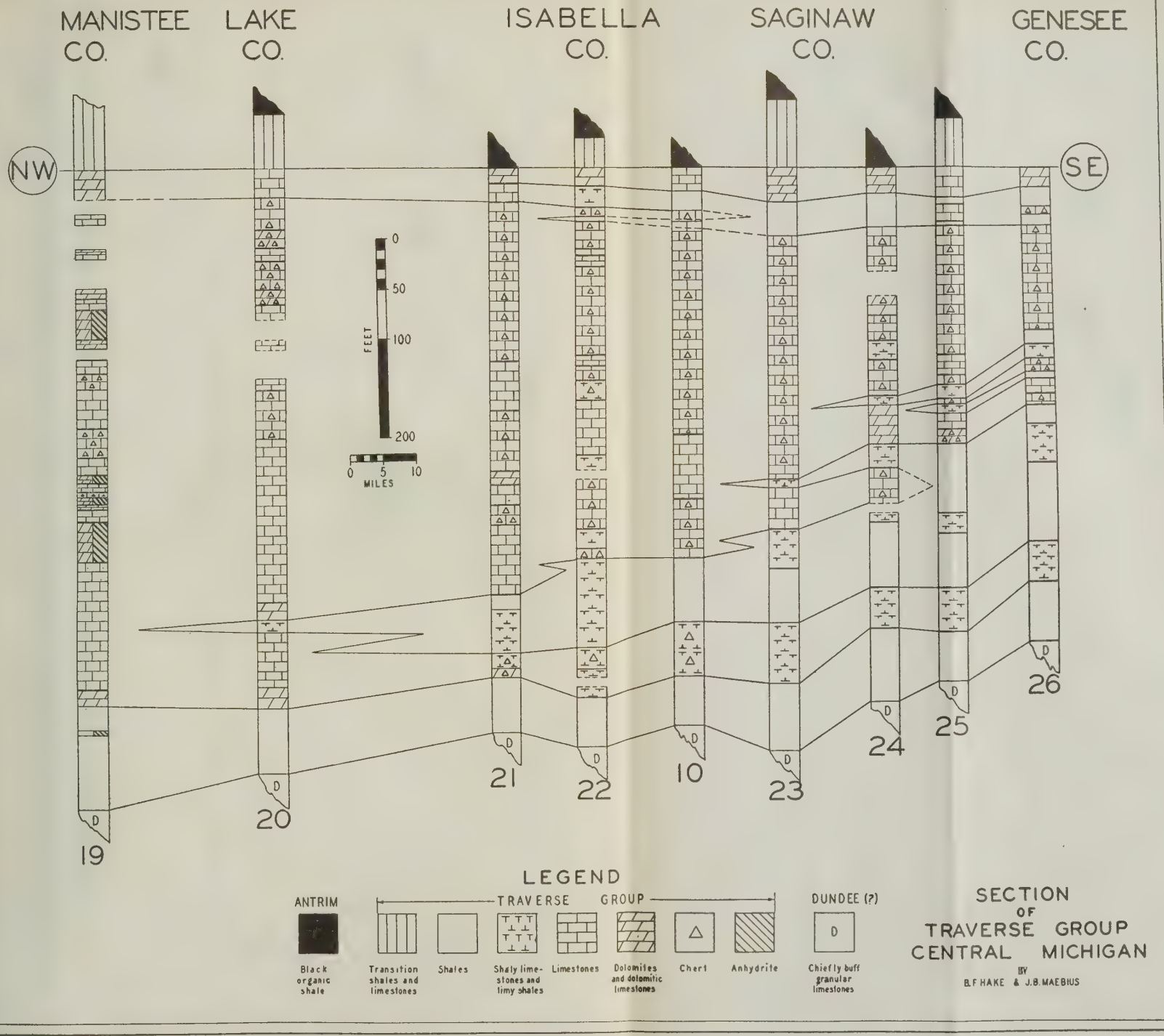
MANISTEE CO.
LAKE CO.
ISABELLA CO.
SAGINAW CO.
GENESEE CO.
NW
SE
0
50
100
200
FEET
0 5 10
MILES
19
20
21
22
10
23
24
25
26
D
LEGEND
ANTRIM
TRAVERSE GROUP
DUNDEE (?)
Black organic shale
Transition shales and limestones
Shales
Shaly limestones and limy shales
Limestones
Dolomites and dolomitic limestones
Chert
Anhydrite
Chiefly buff granular limestones
SECTION OF TRAVERSE GROUP CENTRAL MICHIGAN
BY
B.F.HAKE & J.B.MAEBIUS

FIG. 3

ANTRIM CO.

ROSCOMMON CO.

MIDLAND CO.

SAGINAW CO.

LIVINGSTON CO.

LENAWEE CO.

NW

SE

FEET 0 50 100 200

0 5 10 MILES

27 28 29 30 31 32 24 33 34 35 36

D

LEGEND

ANTRIM — Black organic shale

TRAVERSE GROUP — Transition shales and limestones; Shales; Shaly limestones and limy shales; Limestones; Dolomites and dolomitic limestones; Chert; Anhydrite

DUNDEE (?) — D — Chiefly buff granular limestones

SECTION OF TRAVERSE GROUP CENTRAL MICHIGAN

BY B.F.HAKE & J.B.MAEBIUS

FIG. 4

GEOPHYSICAL MEASUREMENTS IN LIVINGSTON COUNTY, MICHIGAN

WILLIAM G. KECK

IN THE fall term of 1935 an elementary course in applied geophysics was introduced into the curriculum of the Applied Science Division of Michigan State College. It was considered imperative that a certain amount of field work in some of the geophysical methods be incorporated into this course. It is the manner of making these field measurements, and the interpretation of data taken by students engaged in this study, with which this paper is concerned.

In accordance with suggestions made by the State Geological Survey the area to the north and west of Howell, Livingston County, Michigan, was selected as a suitable proving ground for such measurements. Considerable geologic information pertaining to this region is available, and it is near enough to the college campus to permit short field excursions. In selecting the type of measurements to be made the factors of time and expense became very important. The time a student can devote to such work is of necessity limited, and only instruments which are regular equipment in a physical laboratory are available. The method should also be reasonably successful in revealing the known geologic structure. In view of the covering of glacial drift over all of Livingston County this last requirement became especially difficult to meet. Hubbert's [1] work on a similar problem indicates that an areal resistivity survey would be best able to answer all needs.

THEORY OF MEASUREMENT

Several methods of measuring "earth resistivity" are in practical use, differing mainly in the electrode configuration by which current is supplied to the earth and the potential due to this current is

[1] Hubbert, M. K., "Results of Earth-Resistivity Survey on Various Geologic Structures in Illinois," *Trans. A. I. M. E.*, Vol. 110. 1934.

measured. The method introduced theoretically by Wenner [2] and practically applied by Gish and Rooney [3] was employed throughout this work. It will be described briefly.

As may be seen by reference to Figure 1, current, measured by means of a milliammeter, is supplied to the earth through two outer electrodes, from a "B" battery source. The voltage of this source

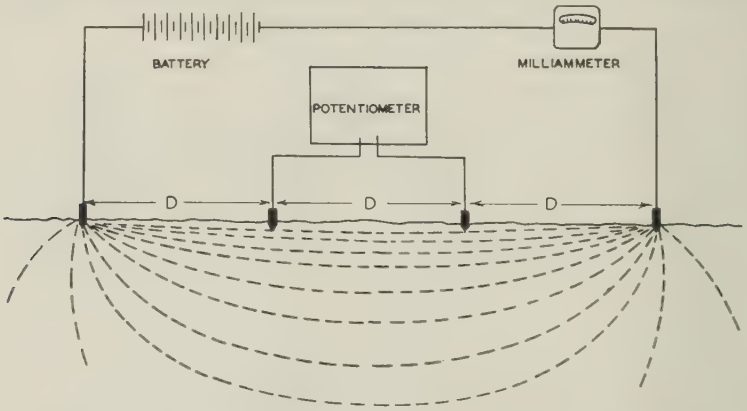

FIG. 1. Schematic diagram of Wenner method of measuring resistivity, showing instruments, arrangement of electrodes, and profile of current distribution between electrodes

ranges from 22 to 500 volts, depending upon the resistance of electrodes to earth. As a result of this flow a potential is developed across the two inner electrodes which is measured with a potentiometer capable of reading to one ten-thousandth of a volt. These potential electrodes are placed on a line with the two outer current electrodes and divide the total distance into three equal parts, which we shall designate by the letter D. If we call the current through the earth I and the potential across the inner electrodes V, the resistivity of the earth material is given, according to Wenner, *op. cit.*, by the equation:

$$\rho = 2\pi D \frac{V}{I}.$$

[2] Wenner, F., "A Method of Measuring Earth Resistivity," *Bulletin No. 258*, U. S. Bureau of Standards. 1916.

[3] Gish, O. H., and Rooney, W. J., "Measurement of Resistivity of Large Masses of Undisturbed Earth," *Terrestrial Magnetism and Atmospheric Electricity*, 30: 161. 1925.

Gish and Rooney, *op. cit.*, state that this value of resistivity is effective for a hemicylindrical volume of length D and radius D situated with its axis between the two potential electrodes.

Having developed the basic principle of making resistivity measurements, we are now ready to consider the two fundamental techniques which govern its field application:

1. Horizontal exploration,[4] or method of the resistivity map. In this method a series of measurements are carried out at various stations, with the same electrode spacing maintained. Thus a horizontal layer of uniform depth is explored.

2. Vertical exploration. A series of measurements is made with increasing electrode spacings at one or several stations. By this means the variation of apparent resistivity with increasing depth of penetration of the current is investigated.

Hubbert [5] has used the horizontal exploration method to detect a buried anticline of massive Devonian limestone, flanked on both sides by younger Mississippian and Pennsylvanian shales and sandstones. Except for a heavier mantle of glacial drift, our problem is very similar to his. To overcome the difficulties introduced by drift materials a modification of the horizontal method has been developed. A description of the theory follows.

Let us assume that at a given station two measurements have been made, each at a different electrode separation. The resistivity at separation D_1 may be called ρ_1, that at D_2, ρ_2. Let us assume, further, that D_2 is larger than D_1. Any change in the apparent resistivity ρ_2 from that of ρ_1 must then be proportional to the amount by which the material between depth D_2 and D_1 differs from that between D_1 and the surface. If we designate the resistivity of the material in the interval between depths D_1 and D_2 by the symbol ρ, we have:

$$(\rho_2 - \rho_1) \propto (\rho - \rho_1). \tag{1}$$

Moreover, any change in apparent resistivity must be directly proportional to the amount, and inversely proportional to the average depth, of the newly added material.

$$(\rho_2 - \rho_1) \propto \frac{2(D_2 - D_1)}{(D_2 + D_1)}. \tag{2}$$

[4] Schlumberger, D. and M., and Leonardon, E. G., "Electrical Exploration of Water-covered Areas," *Trans. A. I. M. E.*, Vol. 110. 1934. [5] *Op. cit.*

When these proportionalities are combined and solved for ρ

$$\rho = \frac{k}{2}\frac{(\rho_2 - \rho_1)(D_2 + D_1)}{(D_2 - D_1)} + \rho_1. \qquad (3)$$

Inspection shows that in the event ρ_2 equals ρ_1, ρ will also equal ρ_1, which is a necessary physical requirement. It remains only to evaluate the constant of proportionality. This must be done empirically. The criterion of a satisfactory value of k is that it be of such magnitude that under no conditions of observed values of ρ_2 and ρ_1 do we obtain computed values of ρ less than zero, since negative resistivity has no physical meaning. Attention should be called to the fact that Wenner's formula holds only for a homogeneous earth. For this reason the apparent resistivity values cannot be accurately interpreted as average values. His formula also holds that the shape of the current path through the earth is such that our assumptions in equation (2) are only approximate. Thus, since we are to interpret equation (3) only as providing a means of comparing relative resistivity values, it follows that an accurate evaluation of k is unnecessary. A value of $k = 1$ has been found satisfactory.

EXPERIMENTAL DATA

Seventy-one stations have been completed in this area, the locations of which are given on the accompanying maps (Figs. 2–4). At each of these stations three separate determinations of apparent resistivity were made, at electrode separations of 100, 200, and 300 feet. From these data it has been possible to compute resistivities, according to the method described above, for the material in the interval between the surface and a depth of 100 feet; between 100 and 200 feet; and between 200 and 300 feet. The experimentally determined apparent resistivities and the interval resistivities computed from them for each station are tabulated at the end of this paper. Each map gives the areal distribution of resistivities for one of these intervals.

INTERPRETATION OF RESULTS

The large Howell anticline has been dealt with at length by Newcombe.[6] In his publication a structural map with contours

[6] Newcombe, R. B., "Oil and Gas Fields of Michigan," *Michigan Geological Survey*, Publ. 38, Geol. Ser. 32. 1933.

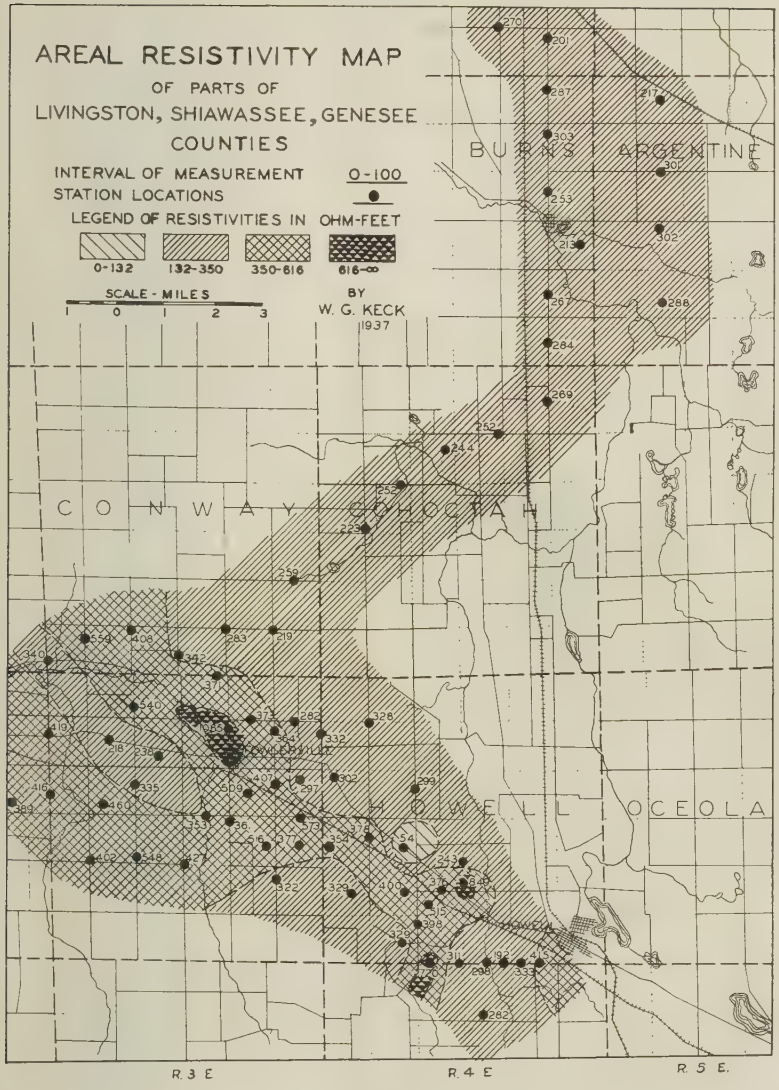
AREAL RESISTIVITY MAP
OF PARTS OF
LIVINGSTON, SHIAWASSEE, GENESEE
COUNTIES
INTERVAL OF MEASUREMENT 0-100
STATION LOCATIONS
LEGEND OF RESISTIVITIES IN OHM-FEET
0-132
132-350
350-816
816-∞
SCALE - MILES
1 0 1 2 3
BY
W. G. KECK
1937
BURNS
ARGENTINE
CONWAY
COHOCTAH
OCEOLA
T. 5 N
T 4 N
T 3 N
R. 3 E
R. 4 E
R. 5 E.

FIG. 2

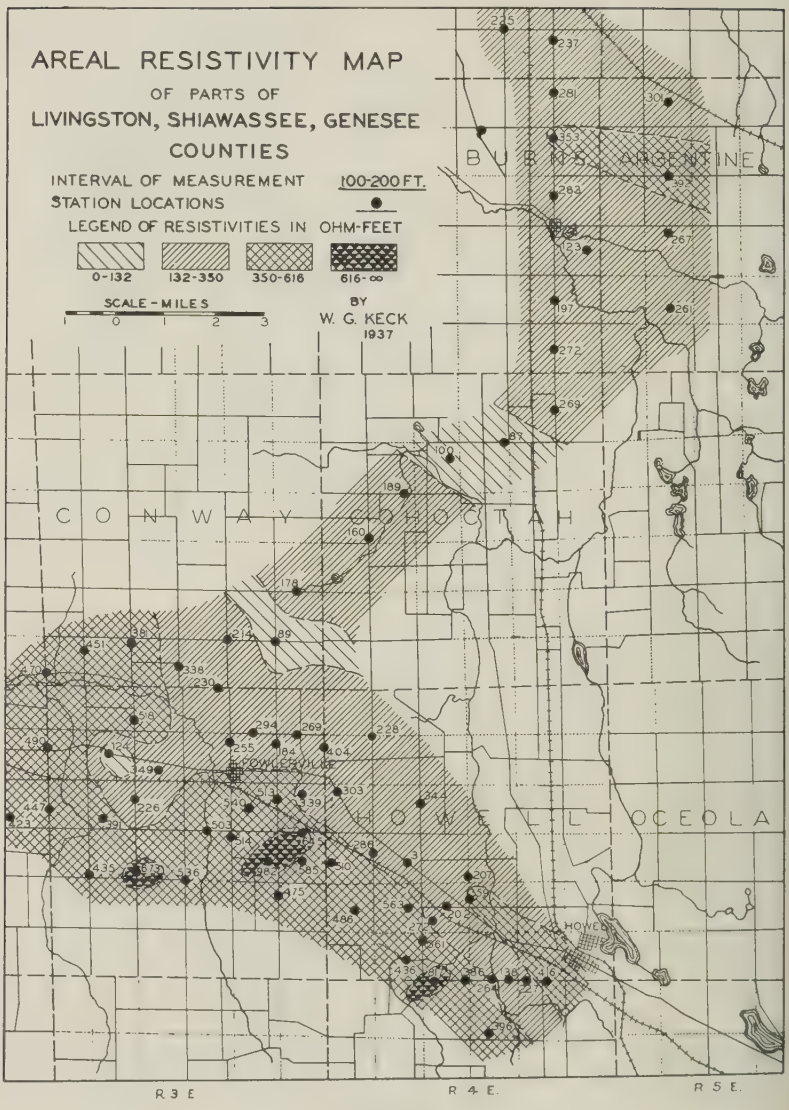
AREAL RESISTIVITY MAP
OF PARTS OF
LIVINGSTON, SHIAWASSEE, GENESEE
COUNTIES
INTERVAL OF MEASUREMENT 100-200 FT.
STATION LOCATIONS
LEGEND OF RESISTIVITIES IN OHM-FEET
0-132
132-350
350-616
616-∞
SCALE - MILES
1 0 1 2 3
BY
W. G. KECK
1937
BURNS
ARGENTINE
CONWAY
COHOCTAH
HOWELL
OCEOLA
HOWELL
T5N
T4N
T3N
R3E
R4E.
R5E.

Fig. 3

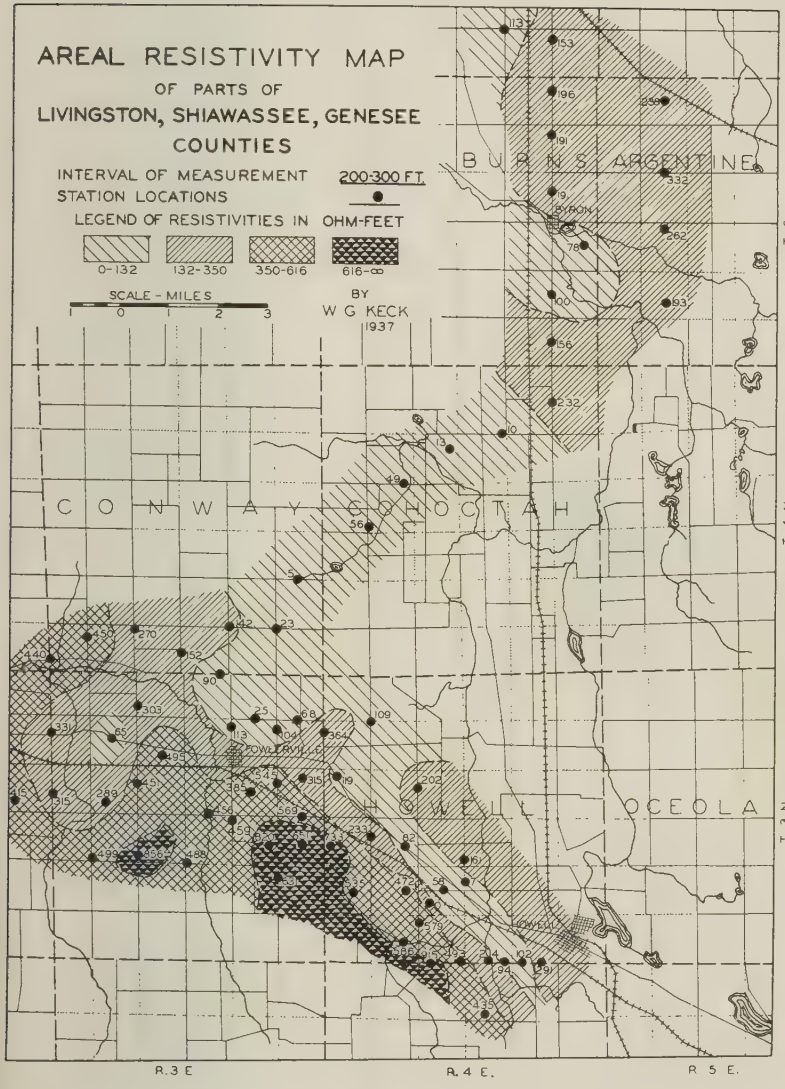
AREAL RESISTIVITY MAP
OF PARTS OF
LIVINGSTON, SHIAWASSEE, GENESEE
COUNTIES
INTERVAL OF MEASUREMENT 200-300 FT.
STATION LOCATIONS
LEGEND OF RESISTIVITIES IN OHM-FEET
0-132
132-350
350-616
616-∞
SCALE - MILES
0 1 2 3
BY
W G KECK
1937
B U R N S
ARGENTINE
BYRON
C O N W A Y
COHOCTAH
H O W E L L
OCEOLA
FOWLERVILLE
T 5 N
T 4 N.
T 3 N
R. 3 E
R. 4 E.
R. 5 E.

FIG. 4

drawn on the top of the Berea, as well as an areal outcrop map, is given. The axis of the anticline is shown to extend in a general northwest southeast direction, plunging moderately to the northwest. Its southwest flank is very steep, but the northeast side has comparatively small dip. The highest part of the structure occurs in the southwest part of the city of Howell, where the Berea sandstone outcrops under, or very close to, the base of the drift. The Coldwater shales, Marshall sandstones, Napoleon sandstones, and Michigan Series members, successively younger beds, outcrop on the flanks of the structure to give the characteristic areal geologic map for a plunging asymmetrical fold.

The first map of resistivities (Fig. 2), which depicts the interval from the surface to a depth of 100 feet, does not reveal any pattern which might be construed as reflecting subsurface structure. This we should expect, since this interval is occupied almost entirely by glacial drift materials. A tabulation of twenty-five wells which have penetrated to bedrock in this region gives proof of this fact.

Drift thickness in wells in feet	*No. of wells*
150 or more	2
125 or more	4
100 or more	11
75 or more	19
74 or less	6

It is to be noted, however, that a zone of high-resistant materials exists in the southwestern part of the area. Wells in Handy Township show an average thickness of drift of 87 feet. It is conceivable, then, that electrically high-resistant sandstones are contributing to these measurements.

Figure 3, for the interval from 100 to 200 feet, should give the resistivity pattern for the bedrock materials immediately under the drift. It ought, therefore, to resemble very closely the areal outcrop map for the region. This resemblance is quite evident. It is to be noted that in the scale of resistivities values higher than 250 ohm-feet may be interpreted as representing the inclusion of considerable sandy material in the interval of measurement. The high-resistant zone to the southwest indicates the presence of the Marshall and

Napoleon formations, and the steep dip of this flank is clearly revealed by the rapid change in resistivity in that direction. Correspondingly, the low dip side is shown by a low rate of change of resistivity in the northeast direction.

Figure 4 exhibits essentially the same features, except that the high-resistant zones have receded farther from the axis and, in general, lower values of resistivity are obtained on the crest of the anticline. This, it is readily seen, must be a consequence of the deeper interval of measurement.

A more detailed check upon these results will be possible when the new map of the areal geology of Michigan, which has been prepared by Helen A. Martin for the Michigan State Geological Survey, is made available.

ACKNOWLEDGMENTS

The writer is indebted to members of the State Geological Survey and to Dr. S. G. Bergquist, of the Department of Geology, Michigan State College, for many helpful suggestions made during the course of this work.

Michigan State College
East Lansing, Michigan

TABULATION OF RESISTIVITIES FOR ALL STATIONS

The three measurements at each station are for depths of 100, 200, and 300 feet, respectively.

Station	*Apparent resistivity* ohm-feet	*Interval resistivity* ohm-feet
1	SW ¼ of NW ¼ of NW ¼ of Sec. 33, T 3 N, R 4 E	
	398	398
	507	561
	534	574
2	SE ¼ of SE ¼ of NW ¼ of Sec. 28, T 3 N, R 4 E	
	376	376
	260	202
	179	58
3	SW ¼ of NW ¼ of SW ¼ of Sec. 22, T 3 N, R 4 E	
	243	243
	219	207
	196	161
4	SE ¼ of SW ¼ of SW ¼ of Sec. 33, T 3 N, R 4 E	
	720	720
	800	840
	846	915
5	SW ¼ of SE ¼ of SW ¼ of Sec. 34, T 3 N, R 4 E	
	298	298
	274	262
	250	214
6	SE ¼ of SW ¼ of SE ¼ of Sec. 35, T 3 N, R 4 E	
	415	415
	416	416
	366	291
7	SE ¼ of SW ¼ of SW ¼ of Sec. 3, T 2 N, R 4 E	
	282	282
	358	396
	389	435
8	SE ¼ of SE ¼ of SE ¼ of Sec. 33, T 3 N, R 4 E	
	311	311
	361	386
	414	493
9	SW ¼ of SE ¼ of SE ¼ of Sec. 34, T 3 N, R 4 E	
	192	192
	156	138
	131	94
10	SE ¼ of SW ¼ of SW ¼ of Sec. 35, T 3 N, R 4 E	
	333	333
	262	227
	198	102
11	NE ¼ of SE ¼ of NE ¼ of Sec. 28, T 3 N, R 4 E	
	849	849
	522	359
	316	7
12	SE ¼ of NW ¼ of SW ¼ of Sec. 28, T 3 N, R 4 E	
	515	515
	353	272
	219	18
13	SE ¼ of SW ¼ of NE ¼ of Sec. 32, T 3 N, R 4 E	
	324	324
	399	436
	474	586
14	SW ¼ of NE ¼ of NW ¼ of Sec. 18, T 3 N, R 4 E	
	302	302
	236	203
	189	119

TABULATION OF RESISTIVITIES (*Continued*)

Station	*Apparent resistivity*	*Interval resistivity*
15	NW ¼ of NE ¼ of SE ¼ of Sec. 20, T 3 N, R 4 E	
	54	54
	20	3
	45	82
16	SW ¼ of SW ¼ of NE ¼ of Sec. 29, T 3 N, R 4 E	
	400	400
	509	563
	494	472
17	SE ¼ of SW ¼ of NE ¼ of Sec. 30, T 3 N, R 4 E	
	329	329
	430	480
	472	535
18	SW ¼ of NW ¼ of NW ¼ of Sec. 25, T 3 N, R 3 E	
	322	322
	424	475
	507	631
19	SW ¼ of SW ¼ of NW ¼ of Sec. 19, T 3 N, R 4 E	
	354	354
	458	510
	568	733
20	NE ¼ of SE ¼ of NE ¼ of Sec. 19, T 3 N, R 4 E	
	378	378
	310	276
	279	233
21	NE ¼ of SE ¼ of NE ¼ of Sec. 17, T 3 N, R 4 E	
	299	299
	329	344
	278	202
22	SE ¼ of SE ¼ of NE ¼ of Sec. 23, T 3 N, R 3 E	
	576	576
	705	982
	751	820
23	SE ¼ of SW ¼ of NE ¼ of Sec. 24, T 3 N, R 3 E	
	377	377
	516	585
	570	651
24	NW ¼ of NW ¼ of NE ¼ of Sec. 24, T 3 N, R 3 E	
	513	513
	581	645
	576	569
25	NW ¼ of SW ¼ of NE ¼ of Sec. 13, T 3 N, R 3 E	
	297	297
	325	339
	321	315
26	NE ¼ of NE ¼ of NE ¼ of Sec. 7, T 3 N, R 4 E	
	328	328
	261	228
	200	109
27	SW ¼ of NW ¼ of NW ¼ of Sec. 7, T 3 N, R 4 E	
	332	332
	404	440
	388	364
28	SE ¼ of SE ¼ of SW ¼ of Sec. 1, T 3 N, R 3 E	
	282	282
	273	269
	195	68
29	NW ¼ of SW ¼ of NW ¼ of Sec. 13, T 3 N, R 3 E	
	407	407
	478	513
	505	545
30	NW ¼ of NW ¼ of NW ¼ of Sec. 23, T 3 N, R 3 E	
	361	361
	463	514
	461	458

TABULATION OF RESISTIVITIES (*Continued*)

Station	*Apparent resistivity*	*Interval resistivity*
31	NW ¼ of NW ¼ of NE ¼ of Sec. 22, T 3 N, R 3 E	
	353	353
	463	503
	460	456
32	SW ¼ of SW ¼ of NW ¼ of Sec. 14, T 3 N, R 3 E	
	509	509
	530	540
	472	385
33	SE ¼ of NE ¼ of NE ¼ of Sec. 11, T 3 N, R 3 E	
	364	364
	244	184
	188	104
34	NW ¼ of NW ¼ of NE ¼ of Sec. 11, T 3 N, R 3 E	
	373	373
	320	294
	202	25
35	SW ¼ of NW ¼ of NW ¼ of Sec. 11, T 3 N, R 3 E	
	1065	1065
	525	255
	360	113
36	NW ¼ of NW ¼ of SW ¼ of Sec. 22, T 3 N, R 3 E	
	427	427
	500	536
	495	488
37	SW ¼ of SW ¼ of NW ¼ of Sec. 21, T 3 N, R 3 E	
	548	548
	631	673
	721	856
38	SW ¼ of SW ¼ of NW ¼ of Sec. 16, T 3 N, R 3 E	
	335	335
	289	266
	354	451
39	NE ¼ of SE ¼ of SW ¼ of Sec. 9, T 3 N, R 3 E	
	238	238
	312	349
	385	495
40	SW ¼ of NW ¼ of SW ¼ of Sec. 4, T 3 N, R 3 E	
	540	540
	525	518
	436	303
41	NE ¼ of NW ¼ of NE ¼ of Sec. 3, T 3 N, R 3 E	
	371	371
	277	230
	204	90
42	SE ¼ of SE ¼ of NE ¼ of Sec. 31, T 4 N, R 3 E	
	554	554
	485	451
	471	450
43	NW ¼ of SW ¼ of SW ¼ of Sec. 31, T 4 N, R 3 E	
	340	340
	427	470
	433	440
44	SW ¼ of SW ¼ of NW ¼ of Sec. 7, T 3 N, R 3 E	
	419	419
	471	497
	415	331
45	NE ¼ of NE ¼ of SE ¼ of Sec. 33, T 4 N, R 3 E	
	342	342
	339	338
	264	152
46	NW ¼ of NW ¼ of NW¼ of Sec. 35, T 4 N, R 3 E	
	283	283
	237	214
	199	142

TABULATION OF RESISTIVITIES (*Continued*)

Station	*Apparent resistivity*	*Interval resistivity*
47	NW ¼ of NW ¼ of NW ¼ of Sec. 33, T 4 N, R 3 E	
	408	408
	390	381
	342	270
48	NE ¼ of NW ¼ of SW ¼ of Sec. 13, T 3 N, R 2 E	
	389	389
	412	423
	412	412
49	NE ¼ of NE ¼ of SE ¼ of Sec. 13, T 3 N, R 2 E	
	416	416
	437	447
	388	315
50	SE ¼ of SE ¼ of NE ¼ of Sec. 19, T 3 N, R 3 E	
	402	402
	424	435
	454	499
51	NE ¼ of SE ¼ of SW ¼ of Sec. 17, T 3 N, R 3 E	
	460	460
	414	391
	364	289
52	NE ¼ of NE ¼ of SW ¼ of Sec. 8, T 3 N, R 3 E	
	218	218
	155	124
	119	65
53	SE ¼ of SE ¼ of SE ¼ of Sec. 26, T 4 N, R 3 E	
	219	219
	132	89
	88	23
54	SE ¼ of SE ¼ of SW ¼ of Sec. 24, T 4 N, R 3 E	
	259	259
	205	178
	125	5
55	SE ¼ of SE ¼ of SE ¼ of Sec. 18, T 4 N, R 4 E	
	223	223
	181	160
	131	56
56	SW ¼ of SE ¼ of SE ¼ of Sec. 8, T 4 N, R 4 E	
	252	252
	209	189
	145	49
57	SW ¼ of SE ¼ of NE ¼ of Sec. 9, T 4 N, R 4 E	
	244	244
	148	100
	94	13
58	NE ¼ of NE ¼ of NE ¼ of Sec. 10, T 4 N, R 4 E	
	252	252
	142	87
	89	10
59	NE ¼ of NE ¼ of SE ¼ of Sec. 2, T 4 N, R 4 E	
	269	269
	269	269
	254	232
60	NE ¼ of NE ¼ of SE ¼ of Sec. 35, T 5 N, R 4 E	
	284	284
	276	272
	228	156
61	NE ¼ of NE ¼ of SE ¼ of Sec. 26, T 5 N, R 4 E	
	267	267
	220	197
	172	100
62	NE ¼ of NW ¼ of SE ¼ of Sec. 24, T 5 N, R 4 E	
	213	213
	153	123
	123	78

TABULATION OF RESISTIVITIES (*Concluded*)

Station	*Apparent resistivity*	*Interval resistivity*
63	SW ¼ of SW ¼ of NW ¼ of Sec. 13, T 5 N, R 4 E	
	253	253
	273	283
	240	191
64	SW ¼ of NW ¼ of NW ¼ of Sec. 12, T 5 N, R 4 E	
	303	303
	336	353
	280	196
65	NW ¼ of SW ¼ of NW ¼ of Sec. 1, T 5 N, R 4 E	
	287	287
	283	281
	248	196
66	SW ¼ of SW ¼ of NW ¼ of Sec. 36, T 6 N, R 4 E	
	201	201
	225	237
	196	153
67	NW ¼ of NW ¼ of NW ¼ of Sec. 35, T 6 N, R 4 E	
	270	270
	240	225
	189	113
68	SE ¼ of SE ¼ of NW ¼ of Sec. 5, T 5 N, R 5 E	
	217	217
	273	301
	259	238
69	SE ¼ of SE ¼ of SW ¼ of Sec. 8, T 5 N, R 5 E	
	301	301
	362	392
	350	332
70	NE ¼ of NE ¼ of NW ¼ of Sec. 20, T 5 N, R 5 E	
	302	302
	279	267
	272	262
71	NE ¼ of NE ¼ of SW ¼ of Sec. 29, T 5 N, R 5 E	
	288	288
	270	261
	239	193

IMPOUNDED EARLY ALGONQUIN BEACHES AT SUCKER CREEK, GREY COUNTY, ONTARIO

GEORGE M. STANLEY

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INTRODUCTION

THE beaches to be described are neither conspicuous nor extensive, but are interesting for the remarkable circumstances of their preservation at Sucker Creek, and especially because they furnish tangible evidence of a lake stage which previously had been only inferred, since nearly everywhere else its shore has been destroyed.

Discovery of these features was incidental to a study of Algonquin and later beaches of northeastern Grey County, Ontario, in September, 1936. Most of the elevations of such beaches here

given are taken from a report [1] on this study, which was aided by a grant from the Penrose Fund of the Geological Society of America. The measurements at Vail's Point were made in September, 1934, as one part of a survey financially aided by the Faculty Research Fund of the University of Michigan.

The sketch maps presented are merely what the term designates, for no real method of horizontal control was employed, and the courses of roads and streams on available maps are only approximated. Probably many small features are sadly distorted from their true position. On the other hand, considerable care was exercised in the instrumental determination of elevations, which, after all, is the only reliable method of approach to a study of changes in level.

The writer acknowledges the fine assistance of Mr. Richard Bilbie, of Ann Arbor, in the field work and the courtesy of Mr. Walter Carson and Mr. Robert Patterson, both of Cape Rich, in supplying local information and implements.

PRELIMINARY DISCUSSION

Methods of Measurement

Spirit leveling was employed in determining the altitudes of nearly all the beaches as well as of other features. This procedure involved starting from Georgian Bay as a base datum (578.2 feet elevation; September, 1936) and sighting against stadia rod with either a pocket level or a telescopic level on tripod. The results are probably reliable in most cases to within 1 or $1\frac{1}{2}$ feet. Most of the figures plotted on diagrams have been taken to the closest even foot. A few aneroid observations included on the diagrams are indicated as such (an.), and though checked usually to some near-by, spirit-leveled point, they cannot be relied on to closer than about 10 feet.

Succession of Lake Stages in Georgian Bay

The following summary of lake history is based on the work of Leverett and Taylor,[2] with certain modifications.[3]

[1] Stanley, George M., "Lower Algonquin Beaches of Cape Rich, Georgian Bay," *Bull. Geol. Soc. Am.*, 48 : 1665–1686. 1937.

[2] Leverett, Frank, and Taylor, F. B., "The Pleistocene of Indiana and Michigan and the History of the Great Lakes," *U. S. Geol. Surv., Mon. 53*, pp. 328 332. 1915.

[3] Stanley, George M., "Lower Algonquin Beaches of Penetanguishene Peninsula," *Bull. Geol. Soc. Am.*, 47 : 1933–1960. 1936.

Algonquin

Lake Algonquin is the earliest, known ancestor of the Great Lakes in the northern Lake Huron and Georgian Bay basins. The highest Algonquin shore line is so marked a feature of the landscape that the geologist can scarcely visit the area without becoming aware of its physiographic importance. Generally it is conspicuous at some distance from the present lake as a rocky cliff, or a high bluff cut into the surface deposits, setting off in great contrast with the lower lacustrine plain the glacial features on the hills above the shore line. It extends across occasional embayed lowlands as an imposing depositional bar. The Algonquin beach has experienced a remarkable deformation. From an area south of the hinge line in southern Lake Huron, where it is horizontal and only 25 feet above lake level, it rises northeastward until it is several hundred feet above Georgian Bay, with a tilt of 3 or 4 feet per mile.

Several stages of Lake Algonquin are recognizable. They are listed here in chronological sequence:

1. Possibly an incipient stage when discharge was at Port Huron and the lake was limited to southern Lake Huron, since the glacier still occupied northern Lake Huron and Georgian Bay. This is a hypothetical stage, for which no beach has ever been reported, although certain terraces along the St. Clair River may have been deposited at this time.

2. The Fenelon Falls (Kirkfield) stage, when the glacier had retreated enough to open the Trent valley and allowed the lake to drain eastward to Lake Iroquois (Lake Ontario basin). This was a prolonged stage, marked by considerable erosion in the Trent valley, but no beach for the lake has hitherto been reported.

3. The "two-outlet" stage, inaugurated when uptilting in the north had elevated the Trent valley and the surface of the lake until discharge began at Port Huron (and at Chicago perhaps). It was during this period of drainage at both Port Huron and Fenelon Falls that "the Algonquin beach" or highest Algonquin beach was formed. The great erosion performed by Lake Algonquin at this time, or during the rise in level which led up to it, quite generally obliterated the previous beaches and left the strong Algonquin shore line, which is prominent. In the discussion that follows it is this stage or its beach that is referred to by the simple term "Algonquin," since such

is the practice on maps and in other reports. The beaches which are the principal subject of the paper are called "early Algonquin" because they antedate "the Algonquin beach," and they ostensibly belong to the second stage of Lake Algonquin noted above.

4. Later stages which formed the "upper group of Algonquin beaches." These are a closely spaced series extending below the highest Algonquin beach (for 40 feet, more or less), found generally in the north and obviously formed during a gradual recession of the lake. Probably continued tilting was now lifting the Trent outlet above the level of the lake, which continued to drain at Port Huron.

Lower Algonquin

After the lowest beach of the upper Algonquin group had been formed rapid lowering seems to have occurred. Several stages ensued, each apparently set off from the earlier and the later ones by an abrupt drop in the lake. Presumably new and lower outlets were becoming available as the glacier melted away from the highlands east of Georgian Bay. Thus followed the Wyebridge, Penetang, Cedar Point, Payette, and perhaps other stages as yet unreported. Only slight tilting took place during the four stages enumerated, for all the water planes are close to parallel, and nearly parallel also with the highest Algonquin plane. The positions of these outlets have not yet been located.

Nipissing

Ultimately the North Bay Mattawa valley carried the discharge of the lakes, and this was the lowest outlet to be opened. Further tilting elevated this outlet and caused the lake to rise until it again overflowed at Port Huron. At this time the well-known Nipissing beach was formed. Resulting from a rise in water, it is similar to the highest Algonquin in prominence and in the abundance of its eroded bluffs. Earlier shore lines were similarly destroyed during the course of its formation.

The Nipissing shore line has been tilted only gently as compared with the Algonquin, for it has been uplifted scarcely more than 100 feet at the most northeasterly points. While this movement was taking place discharge continued at Port Huron, and a group of post-Nipissing beaches were formed, frequently found in the north as

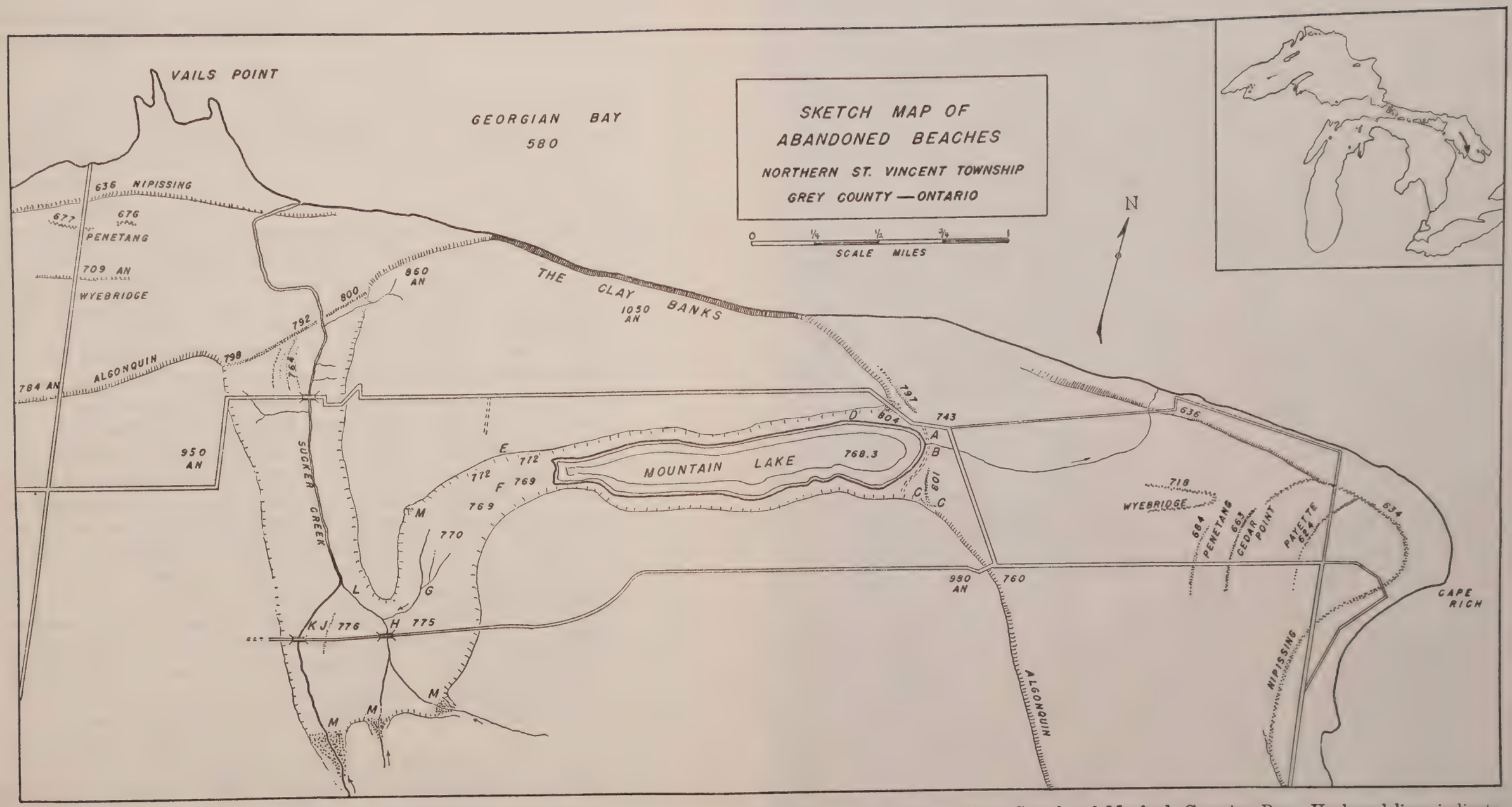

FIG. 1. Sketch map of main features of Sucker Creek–Cape Rich area. Inset shows location, at tip of peninsula between Owen Sound and Meaford, Georgian Bay. Hachured lines indicate wave-cut bluffs and steep hillsides; dotted rows, depositional lake bars or deltas

a number of closely spaced ridges lying in continuous series between the Nipissing beach and the present shore.

Highest Algonquin Shore Line

Among the various lake levels already enumerated the highest Algonquin is especially relevant to the subject in hand, and its beaches in the locality deserve some description. Further details on the lower beaches are given elsewhere.[4]

The highest Algonquin shore, which is a strongly cut terrace and bluff about the entire peninsula between Owen Sound and Meaford, lies a mile or more inland from Vail's Point and Cape Rich. The tip of the peninsula, together with its general location, is shown in Figure 1, on which the Algonquin bluff is represented by a hachured line. Surely this must have been a forbidding coast in Algonquin time, for the bluff is very high and for long stretches towers fully 200 feet above the terrace. North of Mountain Lake about a mile of the Algonquin shore has been cut away by Georgian Bay to form "the Clay Banks," a shore cliff of extraordinary height for the Great Lakes region, since it stands nearly 500 feet above the water.

On the opposite sides of the Clay Banks two deep valleys break the continuity of the former shore cliff. Across Sucker Creek valley stretches a magnificent Algonquin shingle bar, which is rather striking for its bold position and perfection of contour (Pl. I, Fig. 1). It ties to the Algonquin bluff at either end, where it reaches an elevation of approximately 800 feet and is accompanied by short spit beaches in the rear (see Fig. 2). The bar declines to about 792 feet near the middle, where Sucker Creek has cleft it with a deep gorge (Pl. II, Fig. 1). Arrayed along the front slope of the bar are a series of lower beaches, the upper Algonquin group. The lagoon waters have cut into the back of the bar a distinct bench at about 775 feet elevation (Pl. I, Fig. 1).

The valley of Mountain Lake causes a somewhat narrower break in the Algonquin shore cliff to the east of the Clay Banks. Overlooking the southeast corner of the lake is an Algonquin spit beach at an elevation of 801 feet, but for some reason it extends only part way northward across the valley. A little flat terrace (804) at the north corner of the lake, along the road and below the steep hill to the west, seems also a part of the Algonquin shore, as does, of course, a ridge

[4] Stanley, as cited in note 1.

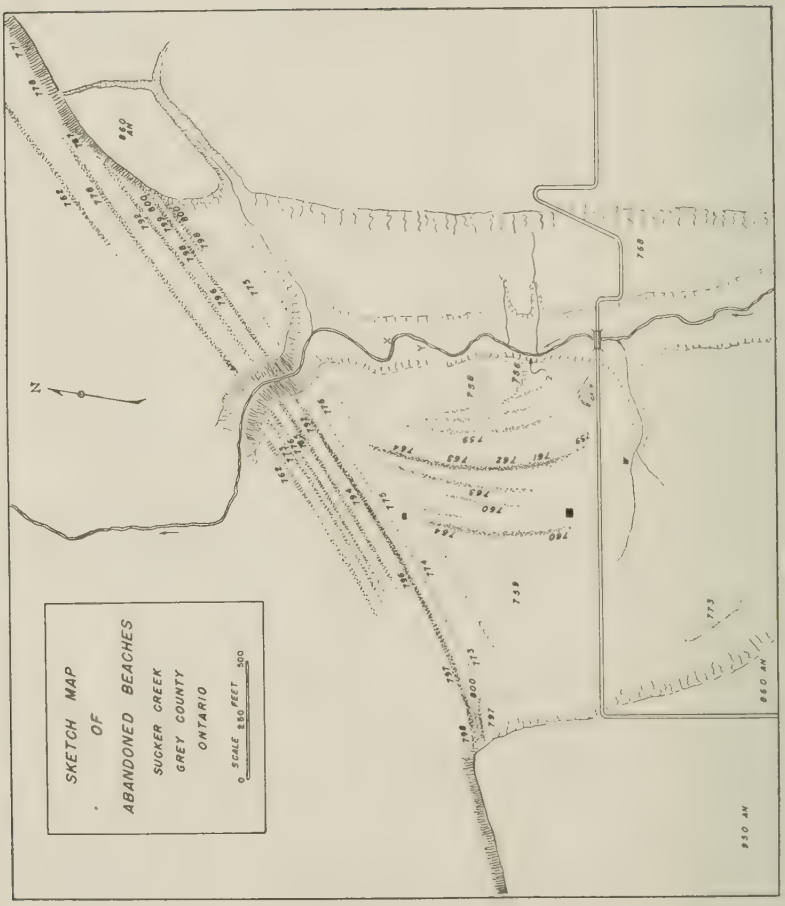

FIG. 2. Plat of beaches and their elevations in Sucker Creek valley. Elevations designated "an." are by aneroid; all others are by spirit level

(797) just north of the road. Northeast and east from the ridges at 797 and 801 feet are a series of lower beaches which cover exactly the same range in level (801 -762) as the upper Algonquin group at Sucker Creek. To avoid complicating the available space these beaches are not plotted in Figure 1.

EARLY ALGONQUIN FEATURES

Shingle Deposits

The first place to suggest the possibility of early Algonquin lake deposits at Sucker Creek was the little gravel pit just west of the highway bridge (Fig. 2). The nicely rounded and stratified shingles in the thick deposit here immediately suggested a shore origin (Pl. I, Fig. 2; Pl. V, Fig. 3). Yet the top of the deposit (758) was clearly some 30 feet lower than the great bar across the mouth of the valley. The waves could not have reached into the creek valley past the bar to work the material, which is spread over a rectangular, level plain stretching nearly a quarter mile south from the great bar. The shingle is exposed not only in the gravel pit but also as talus (Pl. II, Fig. 2) along the west bank of Sucker Creek all the way from the bridge down to the deep gorge. Along the south side of the road across from the gravel pit the shingle stands at a repose slope, occasionally sliding down into the little gully tributary to Sucker Creek. This gully seems to mark roughly the farthest extent of the shingle deposits up Sucker Creek valley. No such rounded material is to be seen anywhere along the creek beyond. The characteristic stream rubble is angular and poorly assorted, utterly different from the nicely rounded shingles, which could scarcely have been worn otherwise than along the shore of the big lake. The only well-rounded, stream-deposited rubble to be seen is at points *X*, *Y*, and, especially, *Z* (Fig. 2), where Sucker Creek has undermined, rehandled, and deposited the typical lake shingles. In an exposure of a little creek terrace at point *Z* the shingles lie like a string of fallen dominoes, all dipping upstream, as flat pebbles are often found in a river bed.

Impounded Spit Beaches

The surface of the shingle plain undulates very gently in a series of flattish north–south ridges. These are all more subdued than the bold Algonquin beach ridges to the north. Some are so obscure that

they almost escape recognition, but two or three are sufficiently definite to draw attention to the rest. The most prominent is in the center of the group, with five elevation values plotted on its crest (Fig. 2). The next one to the west (763) is also definite, and the most westerly is very pronounced. Shingle is to be found on the ridges in small quantities, especially near plow furrows and woodchuck holes, as though brought up from a depth of several feet. The surface is largely of clay. All the ridges are more or less curved and convex to the west. They uniformly reach a maximum elevation of 764 feet, and all extend northward to the fore edge of the bench in the back slope of the great Algonquin bar. From the manner in which they meet this bench they seem almost to pass into and beneath it and beneath the bar itself. Indeed they do, as is shown on pages 486–487. If prolonged lakeward, the converging ridges might come together somewhere north of the high bluff adjoining the northeast end of the Algonquin bar.

It is clear from their form and material that these ridges are wave-formed beach spits, built southward into Sucker Creek bay during an early stage of the lake. Their topographic position makes it certain that they were extended in this direction, as does also the southward decline of two of the ridges. That they antedate the highest Algonquin beach is certain, for they are truncated and overlain by it. Also, since these earlier beaches are nearly thirty-five feet lower than the Algonquin, the lake in which they were formed was here much lower than the two-outlet stage of Lake Algonquin. This is the third situation in which the writer has found fragments of an earlier and lower shore line preserved and protected within an embayment and behind the bar of a higher lake.[5] The older beaches are thus "impounded beaches" and excellent examples of the phenomenon. The impounded Payette beach at Cape Rich has been described elsewhere, but its similar situation is shown in Figure 1. As this map shows, it is unconformable with the Nipissing beach, just as the impounded beaches at Sucker Creek are with the highest Algonquin, and it, too, was submerged at the later stage of the lake and covered with clay.

The material of the impounded beaches at Sucker Creek must have been derived from rock ledges in the bluffs at the side of this former bay; to judge from the curvature of the ridges, it would

[5] Stanley, as cited in notes 1 and 3. The term "impounded beach" was proposed in the paper referred to in note 1.

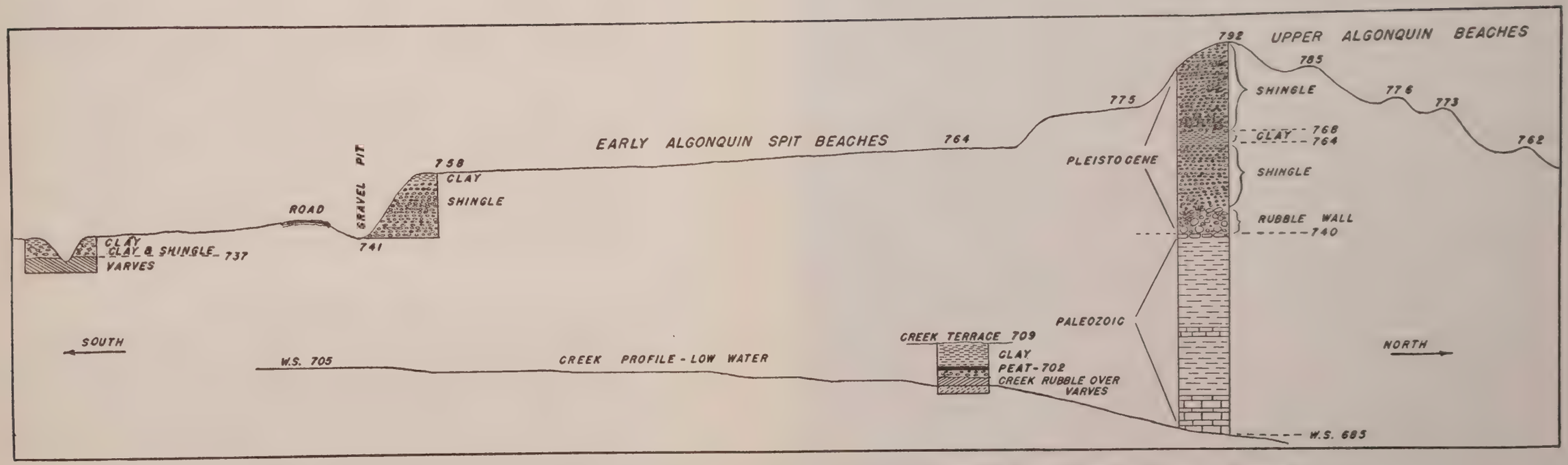

FIG. 3. Idealized profile extending north and south across Algonquin and earlier beaches at Sucker Creek, as shown in Figure 2

appear to have come from the easterly bluff. Without doubt the high hill (860) which furnished the material extended farther north at that time. The very character of the Algonquin shore line implies considerable erosion and cliff recession. Moreover, a little gully in this hill may be traced north to the very brow of the Algonquin bluff (Fig. 2), where the gully is still six or seven feet deep. It seems as though the hill must then have extended several rods north of the present bluff in order to furnish sufficient drainage to cut this channel.

Thus only the distal portions of the beach spits remain. The principal and headward portions of the features, along with the source point of material, were long ago consumed by the avid rising waters of Lake Algonquin. In fact, at the two-outlet stage Lake Algonquin so completely obliterated its earlier shore line that the preservation of the fragments described is truly remarkable; so far they are the only ones on record.

Exposures in the Gorge

The deep canyon where Sucker Creek penetrates the Algonquin bar has been cut down about halfway through Pleistocene deposits and about half through Paleozoic rocks to a total depth of about 110 feet. The precise contact at the bedrock surface is difficult to spot, but seems to be at the base (740) of the very resistant conglomeratic layer, referred to here as the "rubble wall." Beneath this is a thin horizon of angular limestone blocks at the top of the Paleozoic strata, underlain by much-weathered, slumping shales, which, interrupted by one or two harder horizons, continue to the bottom of the gorge (see Fig. 3 and Pl. II, Fig. 1).

The rubble wall is a strongly cemented layer which extends for some distance up and down the valley, at an apparently uniform level (Pl. III, Fig. 1; Pl. V, Figs. 1–2). A three-foot conglomerate mass from this layer was found lying in the gorge below, and its solidity and the embedded stones broken off flush with its surface illustrate the great strength of the rubble deposit. Boulders in it are well rounded and somewhat coarser than the overlying lake gravels, and when they break out their forms are perfectly preserved in the abundant cement (see Pl. III, Fig. 2; Pl. V, Fig. 2). The thickness of the rubble wall is from 7 to 10 feet, though not exactly measurable, inasmuch as it grades into the shingle above. In many places the wall has withstood disintegration better than have the

TABLE I

Elevations of Deposits Exposed in Sucker Gorge*

	Cut I	Cut II	Cut III	Cut IV	Cut V	Cut VI
Base of upper shingle deposit, shingles in clay, overlying pure clay	.....	767.3	767.7	768.2	.....	.....
Sandy streak...	.....	.....	.....	766.3	765.7	.....
Solitary pebble in clay.....	.....	.....	.....	.....	765.0	.....
Summit of lower shingle deposit, clay in interstices....	.....	.....	.....	.....	764.2	764.2
Shingle permeated with clay, at base of cut.	761.0	.....	.....	.....	.....	.....

* The cuts are about 5 or 6 feet apart on the upper part of the west gorge wall, and range from 30 to 60 feet south of the crest line of the Algonquin bar. They were excavated at different levels, each for only a small depth. This explains why figures for a single contact are not given in all columns of the table. Cut I is the most southerly, Cut VI the northernmost.

underlying Paleozoic rocks, and it has recesses and caves beneath it. Occasionally a thin vein of cemented sand occurs at the base of the rubble (Pl. III, Fig. 1).

It seemed at first that the deposits above the rubble wall were one continuous pile of shingle, for a talus of this material masks most of the steep slope. However, an abundance of clay among some of the shingle led to another discovery. Suspended by an eighty-foot line, Mr. Bilbie made six excavations in the hazardous west slope of the gorge and revealed a layer of clay separating the shingle deposits into two beds, one above and one below. Levels were then run down the gorge wall to obtain the elevation of the clay. The results are given in Figure 3 and in Table I. The position of the cuts is shown in Plate II, Figure 1, and in Plate V, Figure 4. The material in the cuts is variously illustrated in Plate VI. The layer of solid clay is 4 feet thick, but clay also permeates the lower shingle and is only gradually replaced by the shingle above.

The lower shingle deposit reaches an elevation (764) precisely the same as that of the summit of the impounded spit beaches to the

south. One need not hesitate to conclude that these ridges continue north beneath the bench and the Algonquin bar, as at first inferred, and that they crop out as the lower shingle deposit in the side of the gorge. Only the upper shingle, and perhaps only the upper part of it, is to be correlated with the highest Algonquin beach and the two-outlet stage of Lake Algonquin.

Interpretations

Any geologist may go to Sucker Creek and read on the ground the facts which have just been presented. Several matters, however, appear to complicate a full interpretation. Two rather different reconstructions may be visualized.

The history of Lake Algonquin as outlined on pages 479–480 calls for a shore line connecting with the Trent outlet, which was everywhere drowned or destroyed to the south by the two-outlet stage. The impounded beaches would seem at once to be a representative of this inferred shore line. The abundance of worn shingle in the features would imply that this early Trent stage was a long one, perhaps fully as long as the stage which formed the Algonquin beach, and would indicate that it was probably much greater than the Wyebridge, Penetang, and other lower Algonquin stages.

It is not difficult to picture the changes brought about at Sucker Creek by the climbing lake level which resulted from uplift of the Trent region. After construction of the westernmost impounded beach, or perhaps a later one, the mouth of the valley may have been graded up to the 764-foot level and a bar thus formed completely across it. As the lake rose, erosion and longshore currents supplied to this bar quantities of material from the neighboring sea cliffs, and the waves steadily heaped the bar to greater heights. The surf now spent its force on this feature, while films of clay were dropped in the quiet waters behind.

Some shoreward migration of the entire bar accompanied its upward building, and it gradually came to cover part of the clay which previously had been deposited in the protected waters behind it. The solitary shingle in Plate VI, Figure 3, was perhaps thrown far back from the limits of the bar by a storm wave, or may have been rafted over its present position by an ice cake. The diminishing mixture of clay with the shingle above the homogeneous clay layer (see Pl. VI, Fig. 4) is a condition which would naturally arise from

the deposition of clay over and among additions of shingle to the submerged back slope of the bar. With the culmination of the lake at the two-outlet stage the summit of the Algonquin bar was completed, and continued uplift caused the waters to recede from this feature and form the series of lower beaches on its fore slope.

No doubt some might interpret the short spits in back of the two ends of the Algonquin bar as formed when the lake stood near the 800-foot level and before the long bar was ever stretched in front of them across the valley. The amassed evidence does not favor this view. That the short spits were developed by surf from the open lake, and not by the waters of the embayment to the rear, is to be inferred from their course and their parallel position with the great bar. Undoubtedly, at the culmination of the two-outlet stage, the ends of the great bar were submerged for some time and the surf which overrode them constructed the diminutive features behind.

It seems curious that the impounded beach spits were built into or up the valley of the embayment, whereas the highest Algonquin beach, at Sucker Creek, as generally elsewhere, formed as a bar directly across the mouth of the bay and shut it off from the rest of the lake. This contrast is probably attributable to some fundamental difference in the conditions of the two lake stages compared, though not enough is known of the earlier stage to enable one to say just what the difference is. Spits are built so as to hook into bays probably because the longshore currents (or surf zone) are unable to traverse the mouth of the bay, and waves or currents deflect the drifting material inward. It seems that great width or depth of the bay might naturally effect construction of hooked spits near the entrance, but that bars might be thrown across the entrance when narrow or shallow. The prevalence of bars enclosing deep embayments of Lakes Algonquin and Nipissing probably traces from the fact that the bars were first completed in shallow water and were then built to greater height as flooding proceeded.

The impounded spits at Sucker Creek suggest a dominance of northeast storms, but there is positive evidence that the Algonquin bar is a product of storms from both westerly and northeasterly quarters, since comparative elevations indicate that material was drifted across the bay in both directions. Theoretically, an absence of westerly storms might have induced the impounded spits to take the course they did.

If, in contrast to the gradual flooding which formed Algonquin and Nipissing bars, a lake was abruptly raised in level, as if by ice advance obstructing the outlet, then river valleys would be immediately and deeply drowned and storm waves could easily sweep into the resulting embayments. Such a condition might easily lead to the formation of hooked spits rather than bay-mouth bars. There is scarcely sufficient evidence to enable one to conclude that such a change in level occurred to develop the impounded spits at Sucker Creek, yet there are grounds for believing that the lake which formed them had previously been lower.

There is a certain uniformity in level of the lowest shingle or lake deposits, 740 feet at the base of the rubble wall, shingle down to 741 or lower in the gravel pit, shingle mixed with clay at several points around 740 along the sides of the gully south of the pit and reaching a minimum level of 737 (Pl. IV, Fig. 1). Extensive shingle deposits at 741 feet do not necessarily imply that the lake stood at or even close to this level when they were deposited. But to this depth at least the valley must have been cleared of such earlier glacial deposits as probably were left there. If Sucker Creek accomplished the degradation, Georgian Bay could have been scarcely higher in level, and therefore an early Algonquin stage may have existed at about the 740–745-foot level here. Probably at that time the stream followed much more closely the west side of the valley mouth than does the present creek. The shingle mixed with mud at *W* in Figure 2 (see also Pl. IV, Fig. 1) would appear to result from occasional pebbles being carried up the valley and lost among fine stream deposits.

Sucker Creek is just 20 miles south of the isobase through the Trent outlet at Fenelon Falls, where the Algonquin beach has an elevation of 870 feet. The average slope of the Algonquin (two-outlet) shore line in this distance is 3.6 feet per mile. An earlier water plane connecting the outlet with the 764-foot beach at Sucker Creek would have the steep slope of 5.3 feet per mile. If tilting alone raised the water from a possible 740-foot level at Sucker Creek to 800 feet, this hypothetical water plane was deformed to a slope of 6.5 feet per mile, but actual knowledge of the 740 stage is wanting.

A second line might be taken to explain the change in lake level from the impounded Algonquin spits to the Algonquin bar. An unconformity (730) in the former sandy lake deposits at Jackson

Point in the Simcoe basin has been reported by Johnston.[6] The locality happens to fall on about the same isobase as Sucker Creek, for the Algonquin beach at both places lies close to 795 or 800 feet, and this should facilitate comparison.

Johnston interprets the barren sands below the unconformity as the product of an early stage of Lake Algonquin at least 50 feet below the two-outlet level at that place. The sands just above (730–735) contain shells identical with those in the highest Algonquin beach deposits near by. The low lake stage (740) which the writer has already suggested for Sucker Creek may well be the same as that which produced the unconformity at Jackson Point. It also seems possible, but less likely, that the 764-foot stage at Sucker Creek is rather to be so correlated with it. Johnston mentions no evidence of a stage near this level.

Johnston supposes, on account of the magnitude of rise at Jackson Point, so close to the Trent outlet, that the flooding could not have been due to uplift alone, but perhaps should be attributed to readvance of the ice. Glacial obstructing of the outlet might similarly be used to explain the rise to the 800-foot level at Sucker Creek, but it would militate against the method of Algonquin bar construction explained in the preceding pages; Taylor's theory of uplift instigating this change seems to the writer more probable.

OTHER FEATURES AND PROBLEMS

Varves

Typical varved clays were seen at numerous points along Sucker Creek. They are exposed in the bank of the creek, at points *X* and *Y* shown in Figure 2, at elevations of 698–702 feet; at several places along the gully south of the gravel pit and up to an elevation of 736, at point *W*; in little gullies in the east bank of Sucker Creek across from the spit beaches, at about 750; at point *L* in Figure 1, elevation 739–758; and at numerous other spots along Sucker Creek. In many places the varves are tilted, dipping 20, 30, or even 70 degrees over a distance of several yards, the reason for which is not understood (Pl. IV, Fig. 2). Possibly some of the varves or laminated clays were deposited in the flooded valley at the Algonquin two-outlet

[6] Johnston, W. A., "The Trent Valley Outlet of Lake Algonquin and the Deformation of the Algonquin Waterplane in Lake Simcoe District, Ontario," *Geol. Surv. Can., Mus. Bull. 23*, pp. 15–17. 1916.

stage, but it seems that most, if not all of them, are generally referable to a much earlier period, when the ice border was near. No counts were made, but if any of the varves are indeed of Algonquin age, they might furnish a good opportunity to read its duration. The varves are overlain at *L* by creek rubble, at *W* by shingly clay, and at *X* and *Y* by other deposits to be described.

Buried Peat Bed

Incised creek terraces (709) at points *X* and *Y* reveal sections like that illustrated in Plate IV, Figure 2, and in Figure 3 (insert). The former creek bed is indicated by the rubble overlying the varves, but this in turn is covered with a horizon of peat from which many sticks and logs protrude. A thick layer of muddy clay surmounts this and furnishes the surface of the terraces. The peat and the mud are obviously features of the post-Algonquin Sucker Creek. The extent and the thickness of the deposits render it unlikely that they have resulted from some recent landslide or winter damming of the gorge. They may represent a limited flooding of the creek at the Wyebridge stage of the lake, when perhaps slight tilting raised the outlet [7] farther north and caused the lake to drown Sucker Creek. Wyebridge beaches cover an interval of 705–718 feet near Cape Rich.[8] A terrace was noted by aneroid (at 709 feet) on the road up from Vail's Point and is shown on Figure 1. An aneroid reading was also taken on a wooded bench (700–705) just to the north of the lowest beach (762) noted on the west side of Sucker Creek, but the bench is not shown on the maps. It seems likely that the buried peat and the overlying mud exposed in the Sucker Creek terraces are contemporaries of all these Wyebridge shore features.

Miscellaneous Benches

From any high point a number of bouldery, undulating, and ancient-looking terraces at accordant levels may be seen extending for miles up Sucker Creek. They are represented at the spots marked 860 an. on Figure 2. They surely indicate a part played in the history of Sucker Creek, but probably so early as to antedate all phases so far discussed. At 830 feet along the lower valley there are a few faintly suggested benches whose meaning is unknown. A distinct

[7] Stanley, p. 1958, as cited in note 3; p. 1684, as cited in note 1.
[8] Stanley, as cited in note 1.

bench was found also at point *E* on Figure 1, elevation 846 feet, but no sure interpretation can be offered.

Problem between Sucker Creek and Mountain Lake

The presence of an abandoned valley connecting the basin of Mountain Lake with Sucker Creek valley offered prospects of explaining puzzling facts at both places. Investigation not only failed to yield a clear solution but resulted in a deeper puzzle well worth noting.

Mountain Lake was measured at 768.3 feet (water surface), but fluctuates seasonally. At about 772 feet a terrace and bluff, an ancient high-water mark, lie back of a narrow beach in many places. This bluff line was found to continue westward at a uniform elevation through the abandoned valley. The deep, broad valley is swampy and wooded near Mountain Lake, with a floor at 769 feet. Toward the southwest end it is cleared, seems slightly higher (770), and is shallowly incised by little tributaries to Sucker Creek, with their bottoms at 768.0 769.4 feet near point *G* on Figure 1, at 765.9 feet near *H* by the bridge. Water surface in the creek was measured at 740.0 feet at *L* and 753.3 at *K* (main branch of Sucker Creek). It is at 705 feet by the highway bridge a mile north. Mountain Lake would have to rise only two or three feet to drain into Sucker Creek; such drainage has occasionally occurred, according to the inhabitants. The writer noted in the woods at point *F* (769) a wooden raft which was probably stranded at such a stage. The old valley is much too great to have been made by this wayward backflowing of Mountain Lake. It was undoubtedly cut by Sucker Creek at some time when diverted from its present lower valley. The bottom of Mountain Lake slopes eastward, for it is said to be deepest at that end. The valley may have been first cut in preglacial times.

The Algonquin flooding of these valleys is witnessed by numerous deltas at 798–802 feet (*M*), by benches at 795 (*D*) and 800 (*E*), and by the fine red clay surface of the flats (775, 776, etc.) around *G*, *H*, and *J*. The clay meets the slopes of the surrounding hills rather sharply and actually seems to "drown" them. It extends down the entire valley of Sucker Creek and is the same kind of clay which covers the spit beaches and crops out in the gorge. A foot or so of it covers the uppermost shingle in the gravel pit, and forms the surface here (758), as is indicated in Figure 3. A buff-colored stony clay

in the high banks overlooking point *X* on the east side of Sucker Creek is different, however, and, though very poorly exposed, is apparently a till deposit.

Why benches are so definitely registered at about 775 feet in the lower part of the Sucker Creek bay is not clear. This seems peculiar in view of the gradual succession of lower beaches formed on the outer slope of the Algonquin bar as the lake withdrew; and perhaps it is a coincidence that the bench along the abandoned valley and the high-water mark of Mountain Lake are at practically the same level. Apparently a close successor of this ponded stage (775) is a rubble terrace (770) of Sucker Creek cut into the higher clay flat (776) at *J*.

It is difficult to understand how the present drainage evolved as the Algonquin water withdrew from these valleys. Since the Algonquin bar (792) must have once extended unbroken across Sucker Creek valley, why, as the lake withdrew, did not the entire creek drain through Mountain Lake to the east? How did it come to dissect the Algonquin bar and to drain north? Certainly no gully could have worked headward on the north slope of the bar, and through it, so as to effect a capture. The beach material is too easily drained.

If the east end of Mountain Lake was once closed off up to the 792- or 800-foot level by a bar similar to that at Sucker Creek, there is no indication of it today. The beaches (797, 801, 804) found there make only a partial attempt at this, and there intervenes a broad gap of low ground 777 to 782 feet in elevation at points *A* and *B* (Fig. 1) which has certainly not been cut away by Mountain Lake creek. In fact, the lake at normal stage, as it was when observed by the writer, seeps eastward underground for a short distance and the water reappears in depressions east of the lake to continue as a creek. Mr. Carson says that it never did naturally overflow here, and overflows now only occasionally in high-water periods by a narrow logging chute which was cut through years ago. Downstream the creek is only a tiny one, its valley scarcely comparable to that of Sucker Creek. There is something curious about the irregular knolls and rolling ground near *A* and *B* which mystified the writer even before the drainage problem had appeared. They have no shape such as might have been imparted by waves, nor do they admit of creek formation or seem artificial. Their irregularity actually suggests some dis-

turbance since the waves abandoned this level. One might conceive of an ice jam thrusting in here during the declining stage of Lake Algonquin and damming the east end of Mountain Lake valley so as to drive Sucker Creek to its present course, but this seems highly improbable because the beach lines do not appear to have been so mistreated anywhere else.

Perhaps the answer to the problem is one of solution. Percolating underground water could possibly have dissolved out limestone beds or lake rubble beneath *A* and *B* and have allowed the whole surface in the vicinity to cave or to settle irregularly. It would seem a phenomenal amount of solution work for so small a trickle of water. On the other hand, apart from these considerations and to judge only from the strength of the Algonquin bars elsewhere, it is a matter of wonder if the bar at 801 feet was never completely extended across this narrow valley.

There remains one final riddle. A narrow little trench (*C–C*) has been cut through the south end of the bar (801), with bottom elevation of 796.3 feet. It is just about the size that might be cut by an overflow from Mountain Lake. How was this cut if the lake could freely drain east over the low ground farther north, or, barring this escape, find another lower exit over the bar (792) at Sucker Creek and four feet below the trench in question?

CONCLUSIONS

1. Fragmentary spit beaches of an early Algonquin lake stage have been preserved at Sucker Creek. They are "impounded" behind a strong Algonquin bar which truncates and partly covers them. They are superior examples of the type of "impounded beaches" which the writer has discovered elsewhere and previously described.

2. These early beaches would appear to bear out the former existence of a strong shore line associated with the Trent valley outlet of Lake Algonquin, previous to and lower than the principal Algonquin beach, just as was long ago inferred by Taylor and others. They are the first recorded bits of such a shore line.

3. This earlier water plane seems to have been tilted nearly 50 per cent more than the principal Algonquin plane.

4. There may possibly have been a still lower, more steeply tilted, previous water plane.

5. The impounded beaches afford evidence of a rise of Lake

Algonquin somewhat similar to that found in the southern Simcoe Basin.

6. There is indication of an upward fluctuation or drowning of the lake for the Wyebridge (lower Algonquin) stage.

7. An abandoned valley and an unsolved drainage complex relate Mountain Lake to the valley of Sucker Creek.

University of Michigan

PLATES I–VI

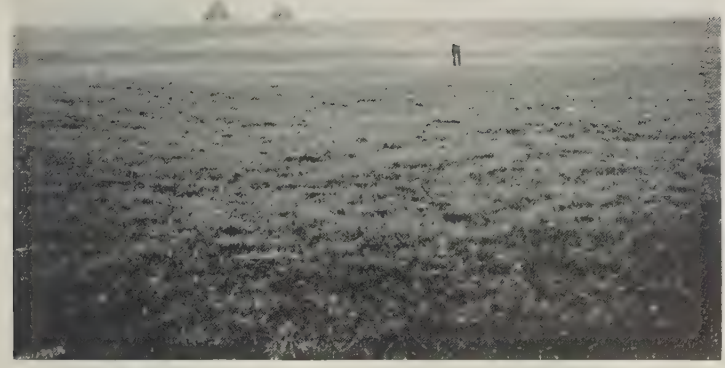

FIG. 1. Part of the great Algonquin bar (795) across Sucker Creek valley. The bench in the back slope is distinctly visible. The man is standing on the principal impounded beach spit (764). View north-northwest

FIG. 2. Beach shingle of the impounded spits; view at gravel pit (see the map shown in Fig. 2)

FIG. 1

FIG. 2

FIG. 1. Northwest view through Sucker Creek gorge. The tiny figure near the large tree at the top of the canyon is excavating in the clay layer. The line of the rubble wall may be seen below

FIG. 2. Talus of early Algonquin beach shingle on the west bank of Sucker Creek

FIG. 1. Base (740) of the rubble wall, and recesses where the Paleozoic rocks have weathered out below

FIG. 2. Close-up of the rubble wall, showing the heavy cement moulds of detached pebbles

FIG. 1. West view of gully at point *W* on the map (Fig. 2), showing the shingly clay overlying varves. In some places the contact (737) is marked by a thin blue marl or clay

FIG. 2. Exposure of terrace on west side of Sucker Creek at point *Y* on the map (Fig. 2). The basal varves are tilted about 20 degrees. The overlying stream rubble consisting of early Algonquin shingle is covered by peat (702), sticks, and several feet of clay (see Fig. 3). The clay is apparently Wyebridge in age

FIG. 1

FIG. 2

FIG. 3

FIG. 4

EARLY ALGONQUIN BEACH DEPOSITS

FIG. 1. The rubble wall

FIG. 2. Close-up view of the rubble wall; contact with Paleozoic rocks at the pipe, or a half foot below (739.8–740.3)

FIG. 3. Early Algonquin shingle in gravel pit. The extent of this thoroughly rounded material indicates a long stand of the lake

FIG. 4. South view of excavations in west wall of the gorge (761–770)

FIG. 1

FIG. 2

FIG. 3

FIG. 4

EXCAVATIONS IN ALGONQUIN CLAY

FIG. 1. Summit (764.2) of lower shingle, permeated with clay; cut VI
FIG. 2. Clay and lower limit (768.2) of upper shingle; cut IV
FIG. 3. Clay and summit of lower shingle (764.2) and solitary shingle pebble (765.0); cut V
FIG. 4. Lower limit (767.3) of upper shingle, which is thoroughly mixed with clay; cut II

AN OCCURRENCE OF NONWETTING SAND AT MUSKALLONGE LAKE, LUCE COUNTY, MICHIGAN

GLENN C. TAGUE

LOCATION

MUSKALLONGE LAKE is situated in northern Luce County, Michigan. It occupies most of Sections 1 and 2 and parts of Sections 11 and 12, T. 49 N., R. 11 W., and extends into Section 6, T. 49 N., R. 10 W. (Fig. 1). It is approximately two miles long and

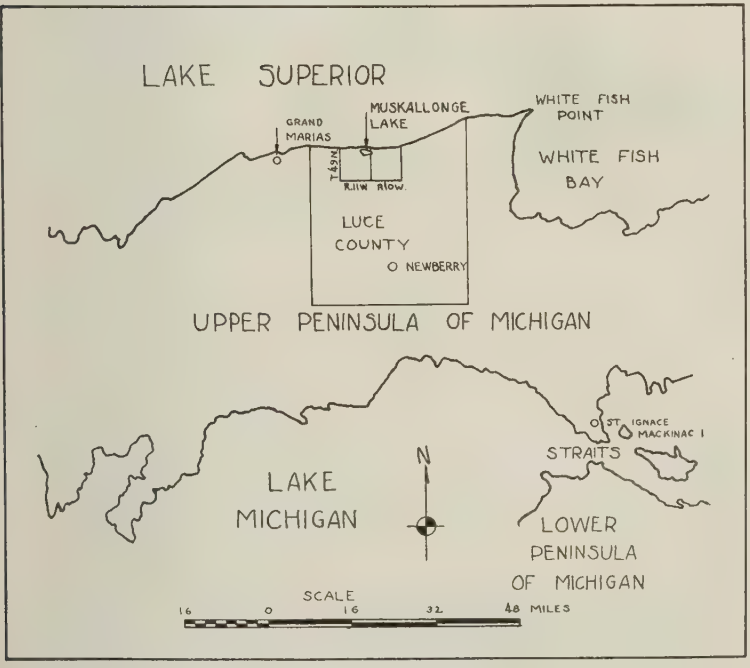

FIG. 1. Location of Muskallonge Lake

one mile wide (Fig. 2). Its northern shore is, on an average, one quarter of a mile from the southern shore of Lake Superior.

PREVIOUS WORK

Until recent years little work has been done in this area. In 1911 Leverett [1] published a map of the surface geology of the Upper Peninsula of Michigan. According to Westerman,[2] no intensive studies of Muskallonge Lake have ever been made, although in 1925 Metzelaar

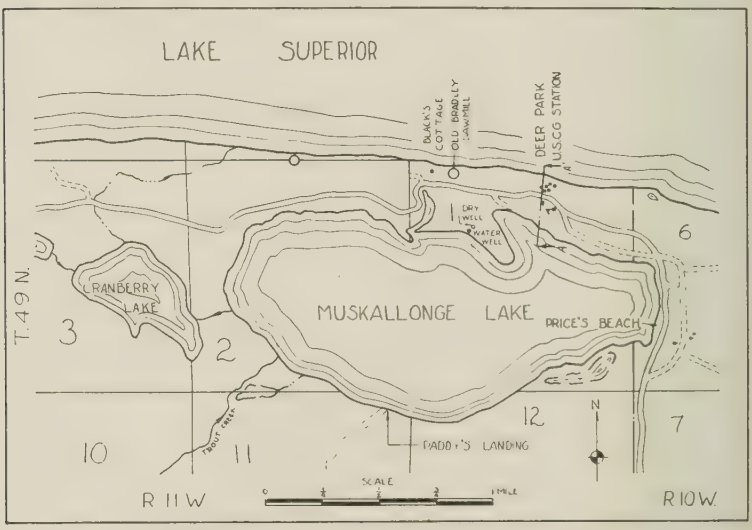

Fig. 2. Detailed map showing Muskallonge Lake and vicinity

and Langlois reported depths ranging from three to six meters. He notes, further, that the Land Economic Survey records the depths of Muskallonge Lake as ranging between ten and twenty feet, with an area of 760 acres. A study of the glacial features and glacial lake beaches within the area has recently been made by Bergquist,[3] who gives a detailed survey of the surface geology of Luce County.

[1] Leverett, Frank, Map of the Surface Formations of the Northern Peninsula of Michigan, 1911.

[2] Westerman, F. A., personal communication.

[3] Bergquist, S. G., "Surface Geology of Luce County, Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters,* 14 (1930) : 437–452. 1931.

Nipissing beaches separate Muskallonge Lake from Lake Superior, an indication that the former lake was a lagoon cut off from Lake Nipissing. Further, it is observed that Muskallonge Lake today stands at the approximate level of this old glacial lake.

LAKE SAND CHARACTERISTICS

During the summer of 1935, in connection with a road materials survey of the Lake Superior State Forest, it was noted that the sand

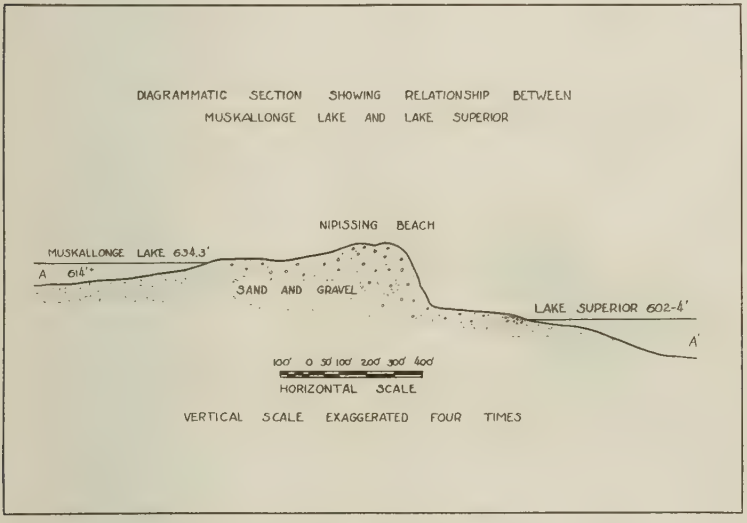

Fig. 3

in the immediate vicinity of Muskallonge Lake exhibited peculiar characteristics when subjected to immersion in water. These characteristics led to further investigations.

A series of levels shows a difference in elevation of 32.3 feet (Fig. 3) between this lake and Lake Superior. Although the lakes are only 610 feet apart at one place, and although the area between consists of sand and gravel, there is very little evidence of drainage by seepage.

Muskallonge Lake has one small outlet at its west end, which is swampy. This outlet drains into Cranberry Lake, which, in turn, empties into Lake Superior by means of an intermittent stream. During the periods of observation this outlet was dry.

Trout Creek, a spring-fed stream, enters Muskallonge Lake from the southwest. It seems improbable, if there is unrestricted seepage between Muskallonge and Lake Superior, that this small inflow could maintain the high water level observed in the lake during the summer of 1935 and again at the close of the summer of 1936. At Price's Beach, along the eastern end of the lake, the state highway from Newberry to Deer Park, which at this point passes within seventy feet of the shore, lies two feet below the level of the lake.

During the spring of 1935 an attempt was made to drive a well to supply the needs of a new state camp ground on the north shore of Muskallonge, in Section 1, T. 49 N., R. 11 W. The well was driven down approximately seventy feet from the shore, but the project was abandoned when water had not yet been encountered at a depth of fifty feet. Later, starting a few inches above the lake level, the Ground Water Survey "washed in" a well thirty feet from the shore. It was dry to a depth of ten feet. This well penetrated only sandy material, and no clay horizon was observed. These facts seem to indicate that the water of the lake does not readily penetrate the sand, and hence causes the water table to drop sharply a short distance away from the shore.

During logging operations in this area a large sawmill was in operation at Deer Park between Muskallonge Lake and Lake Superior. At that time pine logs were floated across Muskallonge, many of which went to the bottom as "deadheads." At the close of logging operations it was considered worth while to attempt to recover the sunken logs. In an effort to drain the lake a channel was dredged northward toward Lake Superior, a few feet east of the line between Sections 1 and 2. This project was stopped by the Government after the channel had been cut to within 610 feet of Lake Superior.

Sand along the beach of Muskallonge Lake displays the marked characteristic of resisting the penetration of water. A handful of dry sand can be held under water for several seconds; when removed, it is found dry on the inside, with a film of wet sand surrounding the dry core. On the other hand, sand along the shore of Lake Superior, a few hundred feet distant, fills with water instantly when submerged.

On calm days patches of sand may be observed floating on the surface of the lake at many places along the shore. Close observation indicates that such sand is unable to break the surface tension of the water.

LABORATORY ANALYSIS

Muskallonge sand, when poured through a funnel under water, takes on a peculiar ropelike appearance (Pl. I, Fig. 1) and remains in this condition for several minutes. Dry sand, when poured into a beaker of water, forms irregular masses (Pl. I, Figs. 2–3) of sand and air. When allowed to stand many of these masses rise to the surface and assume spherical form.

A brief microscopic examination indicates little difference in the mineral content and the grain size between samples of the floating sand and the beach sand. Such study shows that the sand is made up principally of well-rounded quartz grains, some of which contain inclusions of zircon and rutile needles. Some grains were found to be coated with iron oxide. Small amounts of tourmaline, apatite, and altered feldspar were also identified.

Muskallonge Lake sand was (*a*) heated, (*b*) extracted with solvents, and (*c*) treated with inorganic acid in an effort to remove its impervious characteristic. The following results were obtained:

(*a*) Heating the sand to white heat for two hours caused it to lose its imperviousness to water.

A sample was boiled in water for thirty minutes under a reduced pressure of approximately 20 cm. of mercury without noticeable effect on its imperviousness.

Gas was driven off by heating the sand in a large, hard-glass test tube. Carbon dioxide was the only gas detected.

(*b*) Thorough washing of the sand with water failed to change its partial imperviousness to water. Much colloidal material was obtained in the wash water. This failed to settle out completely after a period of one week. The colloid failed to deposit even after two hours in the centrifuge.

A concentrated aqueous extract, made by boiling the sand with water, was tested for traces of tannic acid. Negative results were obtained.

A sample of the sand was boiled for one hour in carbon tetrachloride, by means of a reflux condenser. When filtered and dried, the sand was found to have retained its imperviousness to water. The same procedure was followed with the solvents benzene and ether, and like results were noted.

(*c*) Sand was boiled with three-molar hydrochloric acid for thirty

minutes. When washed and dried, it was found to have lost part of its characteristic imperviousness to water. The filtrate contained iron and aluminum. Sand treated with hot concentrated sulphuric acid in the same manner shows a complete absence of the property and will wet instantaneously when immersed in water.

CONCLUSIONS

It seems probable that Muskallonge Lake retains its relatively high level above Lake Superior because of the somewhat impervious sand that surrounds and may lie beneath it, although only a short distance separates the two bodies of water. The exact cause of this unusual condition of the sand has not been fully determined. It has been established that treatment of the sand with hydrochloric acid partly removes this impervious characteristic, and an analysis of the acid extract shows the presence of iron and aluminum. Further, it has been demonstrated that heating the sand to a temperature of white heat or treatment with sulphuric acid will completely remove this imperviousness.

Further investigation is being undertaken. It is hoped that suggestions will be offered by readers and that similar conditions observed elsewhere will be called to the attention of the author.

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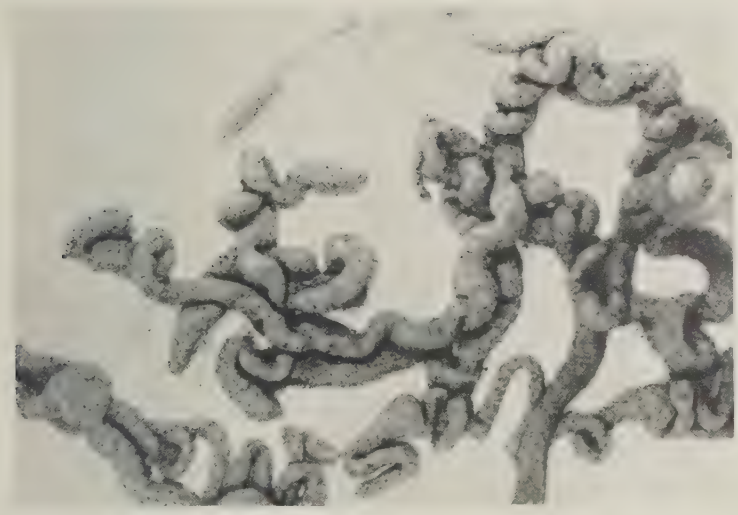
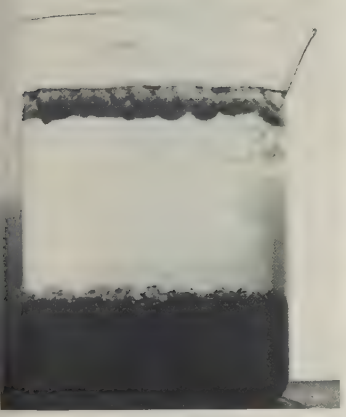


FIG. 1. Ropelike appearance of Muskallonge sand when placed under water through a tube. Note exposed sand on right



IG. 2. Muskallonge sand immersed in water. Note globules of sand floating on surface. This appearance was retained for several weeks

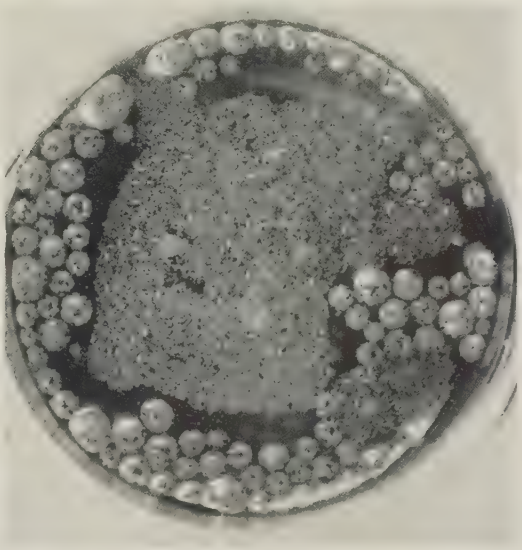


FIG. 3. Surface view of Figure 2

GEOLOGY IN RELATION TO PEDOLOGY

JETHRO OTTO VEATCH

THE geologist's conception of soil has been purely geological. The "kinds" of soil which he has recognized have been determined upon the basis of the origin of the parent material, and he has classified soil by using such terms as "residual," "transported," "alluvial," "eolian," "glacial," "cumulose," or simply according to the kind of rock or the geological formation which might happen to lie beneath it. However, there has been a very considerable divergence, beginning about 1880 in Russia and about 1914 in this country, from this purely geologic concept; and a new science, pedology, has come into being. The pedologist regards soil as a function of: (1) parent material, inorganic or organic; (2) climate; (3) relief and moisture conditions related thereto; and (4) age, or completeness of soil-profile development. The work of the pedologist really begins where that of the geologist leaves off. The pedologist is primarily concerned with what has happened to very recent geologic formations after their deposition and appearance as new land surfaces; and to the residue of rock weathering, or regolith, after its formation on very old land surfaces. He is concerned with the changes effected by elements of climate and by biological forces acting upon the inert or passive parent material. In working out the classification, or taxonomy, he prefers to employ the intrinsic characteristics of the soil itself, rather than causative or environmental factors.

This brief introduction is presented for the purpose of harmonizing the viewpoints of the geologist and the pedologist and making the position of the writer more understandable in the following discussion. The geologist, if not always contributing directly to soil science, supplies foundational knowledge which is necessary for a full explanation of the phenomena of the soil profile and for the differentiation of land into natural divisions upon the basis of combinations of topographic and soil components.

This paper is mainly concerned with Michigan. In reading the publications of the Geological Survey of Michigan it is doubtful whether a single description of a soil profile will be found. This is not to be wondered at, since the conception of the soil profile is of very recent date, even among soil scientists. However, there are numerous references in the publications to the texture and the lithologic composition of the glacial deposits, and inferentially the soil, and to drainage and topography in relation to agriculture and land use. Several instances of relationships between native vegetation and geologic formations are found, and the classic description of the peat deposits of the state by C. A. Davis ("Peat," *Geol. Surv. Mich., Ann. Report for 1906*, pp. 93–361) will be admitted as basic information for the classification of organic soils. Publication 25 (Geol. Ser. 21) of the Geological Survey, *Surface Geology and Agricultural Conditions of Michigan*, by Frank Leverett, has contributed perhaps a greater amount of geological information bearing upon soils and land-type classification than any other single publication.

The chief interest of the pedologist lies in the glacial formations of the state, since these constitute the parent material of most of the soil and also the landforms which must be considered in making a land-type map. The pedologist, however, will not agree that a geologic map of glacial formations is *per se* a soil map. The surface veneer which has resulted from soil-forming processes constitutes the soil proper. The changes due to weathering, which are so important to the pedologist, probably are more extensive than geologists realize. Mature soil profiles are common throughout the state, which implies that marked physical and chemical alterations have taken place in the drift deposits. The processes which make the soil under any particular climate and moisture condition are: (1) accumulation of organic matter on the surface and, concomitantly, soil fauna and flora; (2) leaching and downward movement of soluble matter, formation and translocation of colloids; and (3) the action of water runoff, wind, frost, root penetration, and burrowing animals. The changes from the original character of the drift deposits in Michigan are not great when measured by the thickness of the separate horizons, or members of the soil profile, but nevertheless are sufficient to effect differences in the growth of plants and the agricultural use of land. In general, leaching, the removal of carbonates, and the formation of a B horizon have taken place to depths of

MICHIGAN
GEOLOGIC–PEDOLOGIC RELATIONSHIPS
By J. O. VEATCH
1 Drift generally exhibits strongest limestone influence, but noncalcareous deposits are associated; more clayey drift pale reddish; bedrock at shallow depths; bouldery. 1A, red mixed limestone and sandstone. 1B, red mixed limestone, sandstone, and crystalline rocks
2 Strong sandstone influence, moderate shale and limestone; gray and yellow; high proportion coarse texture; bedrock at shallow depths common
3 Red, diversity of rock influence, with strong to moderate limestone influence. 3A, minimum limestone influence. 3B, chocolate-colored or pale red, less coarse material
4 Gray and yellowish drift, locally chocolate-colored and red till clay northern part; great diversity of rocks with strong to moderate limestone and shale influence. 4A, slate color, strong influence of shale and limestone. 4B, chocolate to slate color, strong influence of shale, less coarse drift. 4C, chocolate to slate color, strong shale influence
5 Pale red, great diversity of rock, strong to weak influence of limestone. 5A, dominant sandy deposits and minimum influence from limestone. 5B, pale red or chocolate color in clayey drift, more strongly calcareous; less coarse drift
6 Pale red and gray drift dominantly sandy; diversity of rocks; slight limestone influence. 6A, pale reddish lacustrine silts and clays highly calcareous
7 Reddish drift, sandy, stony; sandstone and crystalline rock influence dominant; limestone slight and purely local; stony; locally small thickness and rock outcrop
8 Grayish to red drift producing dark red clay and loam soils; strong influence of basic rocks; coarse-textured drift; no limestone or purely local influence. 8A, darker red moderately calcareous silt and clay. 8B, gray and yellow drift; thin covering over bedrock; not calcareous; coarse. 8C, darker red drift and soils; strong influence from iron-bearing rocks; coarse rock outcrop.
NOTE — The heavy boundary extending from Oceana to Alcona County marks approximately the southern limit of hardwood podsol soils which exhibit a marked limestone influence.

FIG. 1

3 to 5 feet, and beneath the B the parent material exhibits in extreme instances some alteration by surficial weathering to depths of 12 to 15 feet. The highly podsolized horizons may vary from clean harsh sand to pulverulent or faintly laminated compact silt. The silt of a soil profile may be mistaken for a thin deposit of loess, and the whole soil profile and the weathered C horizon mistaken for a deposit belonging to a later stage of glaciation than the unweathered till underlying. It should be noted, however, that not all the area of the state exhibits a complete mature or climax soil profile, since perhaps more than a third is occupied by geological soils or those which exhibit only incipient profiles.

Logically, according to the concepts of rock weathering and soil formation held by the geologist, there should be a close relation between soils and the surface formations of glacial origin. The pedologist will agree that a relationship does exist, but will argue that the relationship to glacial features, such as moraines, till plains, and outwash plains, is local and, therefore, not predictable unless other factors, such as the lithologic character of the glacial deposit, the age of the land surface, the details of relief or topography, the climate, and the vegetal cover, are known. The facts which the geologist has supplied regarding the origin of landforms, the age of land surfaces, and the thickness of drift deposits are, of course, basic knowledge which the pedologist should have in order to account fully for the phenomena of the soil profile and the distribution of his soil and land types.

The lithologic composition of the surface deposits, in particular, has a very direct value in the differentiation and the mapping of the soils. Some broad relationships between soils and the lithologic character of the drift may be easily discerned from the accompanying sketch map of the state (Fig. 1).

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THE DEVELOPMENT OF CRITICAL EDITING BY ABBÉ LENGLET DU FRESNOY*

MANSON MILNER BRIEN

AT THE moment when Gutenberg completed his first Bible the problem of critical editing became permanently acute. Since that time both editors and publishers have continually devised suitable reasons to justify reissues of learned tomes. A publisher, seeking profit, pirated a text, had it emended, and offered a volume which copied all the original faults to the letter. Later disclosures, always an excuse for another printing, were added to doubtful material until it required a genius to determine the original text. Scholars were scarcely more diligent than publishers in their investigations. Unless men of letters were independently wealthy, had powerful backing, or presented some extremely popular book, they had to depend upon their publishers' gambling instincts. Thus many worthy discoveries often either failed to reach the public or were brought out in an unattractive format which invited immediate neglect. Consequently the eighteenth century possessed a welter of knowledge, divided by tremendous gaps and largely unclassified, wherein both truth and falsity were inextricably confounded.

There was, however, a brighter side to this lack of system. Men of rugged individuality, striving to produce better volumes than those of competitors, constantly sought innovations. During the

* The following abbreviations for the works and editions of Lenglet du Fresnoy are used in this paper.

Arrêts. Les Arrêts d'amours (Amsterdam: Changuion, 1731), in-12.

Marot. Œuvres de Clement Marot (La Haye: Gosse et Neaulme, 1731), 4 vols. in-4°.

MPEH. Méthode pour étudier l'histoire (Paris: Gandouin, 1729), 4 vols. in-4°.

PH. Histoire de la philosophie hermétique (Paris: Coustellier, 1742), 3 vols. in-12.

Rose. Le Roman de la Rose (Amsterdam: Bernard, 1735), 3 vols. in-12.

Sup. Supplement de la méthode pour étudier l'histoire (Paris: Rollin fils et de Bure l'aîné, 1739), 2 vols. in-4°.

Usage. De l'usage des romans (Amsterdam [Rouen]: Veuve Poilras, 1734), 2 vols. in-12.

course of years prefaces, *avertissements*, notes, documentation, biographies, bibliographies, and glossaries came into existence.[1] Hence, unconsciously, scholarship and trade developed all the paraphernalia of critical editing. But these procedures were still sadly lacking in standardization, unity, and exactitude. Such, briefly, was the situation which confronted Abbé Nicolas Lenglet du Fresnoy when he seriously examined the problem of critical editing and which he determined to remedy.

Abbé Lenglet (1674–1755) was a scholar and a historian, a jack of all literary trades and master of most of them.[2] He was widely experienced in research work and in editorial labor, so that his attack was straightforward, caustic, and justified.

He criticized one editor for not indicating variants, not correcting expurgations, and not rectifying historical errors by notes; also for not citing printed works and documents employed, for not recording where manuscript sources might be found, and, finally, for not inserting marginal summaries in a long continuous text.[3] He wrote savagely about another scholar: "The author marks no citations in his book. That is not pardonable in a modern writer."[4] Again, the Abbé scorned a famed historian because he placed too much confidence in recent volumes and did not go back to the sources.[5] On the

[1] To trace the origin of these points is beyond the scope of this paper. All of them, as well as the arts of collation and of textual criticism, had been employed before the Abbé's age and are found in the works of the Godefroys, Duchesne, Secousse, La Monnoye, Le Duchat, Brossette, Coustellier, and others.

[2] For a short sketch of his life see Manson Milner Brien, "Lenglet du Fresnoy: a Biography," *Pap. Mich. Acad. Sci., Arts, and Letters*, 18 (1932): 457–478. 1933.

[3] *Sup.*, 2: 161–162. Regarding Jacques de Thou's *Historiae sui temporis* (London, 1733), Lenglet wrote: "On peut dire néanmoins que cette Edition auroit pû être beaucoup plus parfaite. 1° Il auroit fallu y mettre les différences de l'Edition du premier volume de Mamert Patisson. 2° Les différences de l'Edition de Francfort. 3° Les endroits retranchez qui se trouvent en manuscrits. 4° Faire voir par des notes les fautes historiques commises par M. de Thou. 5° Expliquer par des notes les qualitez et les familles des personnes dont parle M. de Thou. 6° Marquer les Editions des piéces dont s'est servi M. de Thou, ou quand elles sont restées manuscrites désigner où elles peuvent être. 7° Diviser l'ouvrage par numeros et y faire la Table des matiéres relative. 8° Mettre des Sommaires très-fréquens aux marges du texte; parceque M. de Thou écrivant d'un Texte continu, c'étoit à l'Editeur à marquer la différence des matiéres."

[4] *MPEH*, 4: 238.

[5] *Sup.*, 2: 55. Here Lenglet was accusing Rollin: "De s'en être rapporté avec trop de confiance à des Auteurs modernes, qu'il a exactement copiés sans recourir aux sources."

other hand, he decried nonpertinent historical or philological notes.[6] He mocked pseudo erudites who made a vulgar display of learning in unnecessary Latin or Greek citations.[7] He became satirical at the expense of publishers who merely altered a title page in order to announce a new edition, or who, simply for profit, rushed into print with a mediocre book.[8]

Throughout fifty years these points formed the basis of Abbé Lenglet's criticism. Risking censorship and imprisonment he drove them home by brief mordant remarks which rendered him anathema to the savants of his age.[9]

His genius was, however, far more constructive than destructive. Coincidentally with his scathing onslaughts he preached the fundamental procedure necessary to prepare a worth-while edition. Above all, he reiterated, a skilled man alone should undertake the task, for the public was not to be deceived by mediocre workmanship.[10] Regarding the purely mechanical steps he laid out the following program: to show all suppressed passages, to indicate all editions, to clarify essential facts, to correct dates, and to join the necessary proofs.[11] Should the study involve the restoration of a text the Abbé

[6] *Usage*, 2 : 555. He was speaking about the 1711 edition of Rabelais by La Monnoye and Le Duchat.

[7] *PH*, 1 : iv–v. "Peut-être . . . que j'aurois pu le charger (cet ouvrage) d'un grand nombre de citations Grecques et Latines, qui auroient plû aux Sçavans. . . . Qu'un autre plus habile et plus laborieux cherche donc à ennuyer le Public par des Compilations de Passages; pour moi, je suis content d'instruire, et de le faire d'une maniére claire et succincte."

[8] *MPEH*, 3 (Part 2) : 62, 271. Criticizing Louis-Ellies Dupin the Abbé wrote: "Il prétendoit seulement faire un livre en 6 volumes qui pût produire quelque profit au Libraire et à l'Auteur." Likewise about the 1702 and 1707 editions of the *Scriptores rerum Germanicarum* he commented: "Peut-être ces deux éditions ne différent-elles que dans la datte et la premiere page. C'est l'usage des Libraires d'en user ainsi pour montrer que leurs livres se débitent beaucoup."

[9] Brien, Manson Milner, "The Censorship of Lenglet du Fresnoy's *Méthode pour étudier l'histoire*, 1729," *Pap. Mich. Acad. Sci., Arts, and Letters*, 19 (1933) : 427–439. 1934. Relates the abrupt alteration which a few of Lenglet's remarks met at the hands of the censor.

[10] *PH*, 3 : 231; *Usage*, 2 : 276.

[11] *MPEH*, 4 : 41–42. The following lines appear in a long discussion on de Mezeray's *Abrégé de l'histoire de France*: "Pour faire un bon ouvrage, il faudroit comparer toutes ces éditions, et en faire une nouvelle où l'on marqueroit les endroits supprimez dans les premieres éditions, et les endroits ajoutez dans les éditions posterieures. Il faut y rectifier beaucoup de faits essentiels qui sont développez imparfaitement, corriger quelques dattes et joindre en preuve des actes et des titres nécessaires pour la connoissance des affaires publiques."

made it a cardinal principle that an editor employ as a base the best possible manuscript or printed edition. This he must supplement by noting all related works, marking all variants, and adding glossaries.[12] Then he must examine his source material and choose his documents with rigorous care.[13] Finally, he must subject the text itself to a searching internal critique in order to answer any unsolved difficulties of biography or composition.[14]

Lenglet not only criticized and preached; he went further and displayed the feasibility of his designs by their actual execution. His interests led him, since he was more venturesome than most scholars, to pioneer in those least-known periods, the later Middle Ages and the sixteenth century. He was perhaps the only research man of his own age sufficiently experienced and well rounded to investigate these fields when a very fortunate and peculiar conjunction of circumstances made it possible. The "Quarrel of the Ancients and Moderns" had given French a primacy at least equal to that of York. Hence the origins of the language lay open to examination. This task, itself, became feasible as a result of Mabillon's *De re diplomatica*, which had conceived nearly full-grown the sciences of diplomatics and paleography. At the same time the perfection of editorial forms by the book trade invited scholarly publications.

[12] *Usage*, 2 : 234. With regard to the forthcoming restoration of the *Roman de la Rose* Lenglet stated: "Elle est faite sur les plus anciennes Editions et non sur celles de Clement Marot. . . . On y a mis un Glossaire pour l'explication des vieux mots de notre Langue qui se trouvent dans ce Roman. . . . Les differences sont raportées à la fin du troisiéme volume."

[13] Lenglet du Fresnoy, ed., Pierre de l'Estoile, *Journal de Henri III* (La Haye et Paris: Veuve Gandouin, 1744), 5 vols. in-8°; 1 : xv: "Il n'y a que ceux qui sont livrés à de pareils Ouvrages, qui puissent connoître la peine que l'on a de bien choisir dans un nombre presque infini de Livrets, de Satyres et de Feuilles volantes, qui se publioient dans ces temps orageux." See also *ibid.*, 4 : x–xi: "J'ai eu recours aux Originaux qui se trouvent aujourd'hui précieusement conservés dans la Bibliothèque de sa Majesté; c'est au Numéro 9128 parmi les manuscrits de M. de Bethune. . . . Il n'y en avoit dans les anciennes éditions que quarante et j'en ai trouvé dix-neuf de plus, ce qui fait cinquante-neuf Lettres que je présente dans cette nouvelle Edition. . . . Henri ne designe jamais l'année. C'est un travail que j'ai pris sur moi; et par les faits ou les circonstances du tems, indiquées dans ces lettres, j'ai eu soin d'y rétablir l'année.

[14] *Ibid.*, 5 : 603. Here is another pointed example of Lenglet's internal criticism, "François Villon, l'un de nos meilleurs Poëtes François, naquit à Paris l'an 1432; puisque sur la fin de l'an 1461 qu'il fit son grand Testament, il se dit dans la trentiéme année de son age. Il étoit *Enfant de Paris*, comme il le marque lui-même au Vers 1057 de son grand Testament; ainsi par cette autorité, on fait tomber tout ce qui se dit au contraire."

Furthermore, there was a distinct revival of interest in the Middle Ages and the sixteenth century. Sensing these factors Abbé Lenglet brought out a complete *Marot* and an *Arrêts d'amours* in 1731. Two years later he pirated Brossette's *Régnier*, greatly improving the glossary and the notes. In 1735 he restored the *Roman de la Rose* to its original form. During 1741 and 1744 he edited the *Journal* of Pierre de l'Estoile, and he continued his labors by a new *Comines*, published in 1747, which he followed by a superb *Lactantius* within the next twelve months.[15] So precisely did the Abbé work that these volumes clearly display his entire critical method.

For convenience we may summarize his procedure under six main points. First, he required the establishment of the text. He was among the earliest, if not actually the first, to make collation an invariable step, and he published only when he had a manuscript or a perfected volume as a base. For the *Roman de la Rose* the primary text was the Vérard Quarto of 1500, the best of all the early printings.[16] He compared this in detail with the Coslin manuscript and fragments from His Majesty's Library and from "S. Germain des Prez."[17] The 1596 volume by Nyort became the foundation for the *Marot*. This Lenglet collated with manuscripts, old editions, and separate issues which he dug from the literary débris of the sixteenth century.[18] As the basis of the *Comines*, he chose the oft-reprinted book of the Godefroys, but he corrected it from the Dobrée manuscript of Saint Germain des Prés and sought other assistance from Sleydan and Sauvage.[19] From such sources he drew up the variants

[15] The following are the full titles of these editions:

Lenglet du Fresnoy, ed., *Satyres et autres œuvres de Regnier* (Londres [Amsterdam]: Tonson, 1733), in-4°.

Journal de Henri III; see note 13.

Journal de Henri IV (La Haye: Vaillant, 1741), 4 vols. in-8°.

Memoires de Messire Philippe de Comines (Londres et Paris: Rollin, 1747), 4 vols. in-4°.

Lucii Caecilii Firmiani Lactantii opera omnia (Paris: J. de Bure, 1748), 2 vols. in-4°.

For the *Marot*, *Arrêts*, and *Rose* see the introductory note.

[16] Bourdillon, F. W., *The Early Editions of the Roman de la Rose* (London, 1906), p. 189.

[17] *Rose*, 2 : 424, note; Claude Pierre Gouget, *Bibliothèque françoise* (Paris: Mariette et Guerin, 1745), 9 : 58.

[18] *Marot*, 1 : xx and 114–116; Gouget, *op. cit.*, 11 : 62.

[19] Michault, J.-B., *Mémoires pour servir à l'histoire de la vie et des ouvrages de Monsieur l'abbé Lenglet du Fresnoy* (Paris et Londres, 1761), pp. 184–185; Calmette, Joseph, ed., *Mémoires de Comines* (Paris, Champion, 1924), p. xxvi.

which he deemed absolutely necessary to incorporate. He employed in these tasks every known philological and historical aid to produce a text as accurate as possible. With a frankness uncommon in his age he set forth his sources, generally stating their provenance in detail and often going so far as to cite the library call number, as he made a final plea that other scholars check and continue the labor.[20]

Second, the annotation of the text was a vital factor. Lenglet realized that no commentary is valuable unless it is useful.[21] Therefore, all notes should be clear and succinct.[22] They should not overwhelm but accompany a text.[23] The stupendous *Marot* admirably illustrates the extent to which he carried these requirements. He cited more than fifty-three fifteenth- and sixteenth-century authors in order to explain minutely the historical, philological, and literary background, as well as the progress and the adaptations of Marot's thought. Not one interpretative stone was left unturned. But in the *Roman de la Rose* the Abbé's critique was not so thorough. His notes were extensive but not extensive enough. He, however, was the first to admit this defect, acknowledging that the pressure under which he labored did not permit a remedy. Hence he offered his work merely as a stimulus to others who might carry on.[24]

Third, he desired that all reprints of early writers include a glossary. "How scholars would be satisfied," he wrote, "if this conduct had always been used in new editions of old authors who serve as the foundations of our literature and our modern language."[25] Thus he wanted each volume made sufficient unto itself, a practice which would render unnecessary the defective dictionaries of the period.

Fourth, the Abbé transformed the preface from an obvious prospectus into a vehicle for criticism. Although his own prefatory remarks were often witty and daring, they were highly informative,

[20] See note 13. Another example of this practice is found in the bibliography of his *Histoire de Jeanne d'Arc* (Paris et Orléans: 1753–1754), 3 vols. in-12; 2 : 187–188.

[21] *MPEH*, 3 (Part 2) : 89.

[22] *PH*, 1 : v; see also note 6.

[23] *MPEH*, 3 (Part 2) : 61. Concerning the *Abrégé de l'histoire universelle* by Père Turselin, Lenglet said: "Cet ouvrage ne surpasse l'original que par un grand nombre de notes, dont il est plûtôt accablé qu'accompagné."

[24] *Rose, loc. cit.;* Gouget, *op. cit.*, 9 : 59.

[25] *Arrêts*, pp. xxvii–xxviii. Abbé Lenglet, of course, did not originate this idea, but he was the first who stressed it and acted consistently upon it. "J'en useraı de même dans nos anciens auteurs que j'ai dessein de reimprimer. Par-là chaque livre se pourra suffire à lui-même."

for he constituted himself a complete guide for the reader. He discussed the lives of the authors, their tastes, and their backgrounds, analyzed the text, attempted to solve all entanglements, noted sources and previous printings, and offered his own opinions and the plan of his edition. Every one of Lenglet's important prefaces contained biographical data constructed upon an internal analysis of primary material. The life of Marot was built up and the details proved by citations from his poetry. This also holds true for the lives of Guillaume de Lorris and Jean de Meung, wherein the Abbé exposed the errors of prevailing conceptions. Before plunging into the *Comines* he was practically forced to rewrite the history of the epoch. His prefaces served too as a vehicle for literary discussion. The poetry, rhyme, and versification of both Marot and the *Roman de la Rose* underwent a careful scrutiny. Indeed, Lenglet tried to neglect no factor vital to a thorough textual comprehension.[26] Naturally, modern research has from time to time demonstrated his mistakes, but we must remember that he was venturing into a little-known field and that internal criticism was then a practically unsubstantiated process.

Fifth, he warned editors not to rush into print simply because of a new discovery. Although he wished that all rare manuscript sources might be fully reproduced, he made their editing serious work. They had to be well chosen and pertinent to the details of a central objective. He himself found and published nineteen letters of Henry IV, and his comments on this labor show the care lavished on one unimportant edition.[27]

Sixth, and this sixth precept might be a godsend to present-day impecunious scholars, he always edited for profit and hence gave his books an appeal beyond pure learning. He knew that the scholarly public and the salon public represented widely different attitudes and that the purchasing power lay with the latter. Therefore his work made a definite bid for recognition among the wealthy, the

[26] One may examine the editions cited in note 15.

[27] See note 13. There were numerous occasions when Lenglet did not strictly maintain this attitude. When he brought out a work for profit, he generally filled out the formes by extraneous material. His defense was that these documents were rare and worthy of preservation. At such times he subjected them to the same editorial scrutiny as he gave a major text. Thus his minor editions present the paradox of a commonplace book followed by a well-edited, but unknown treatise.

witty, and the superficially cultured. Excellent craftsmanship distinguished every edition; the volumes were large quartos and folios, with the best possible type and the finest Holland paper. He had the pages framed in red or black borders, and he entrusted the making of vignettes and other ornaments only to skilled engravers. Every tome, page, and line represented the highest efforts of individual labor and delicate aesthetic taste. Lenglet's books looked impressive in a library.[28]

But he sought to carry superficial attraction beyond appearance. Realizing that the fashionable world was far more interested in personalities than in scholarship, he indulged his audience with spicy comments about various writers and publishers. Generally his remarks were substantial, justified criticism, but sometimes — as in the case of Coustellier, "a good bookdealer and archcuckold" [29] — they were facetious. All in all such sallies probably sold many a volume which otherwise would have suffered neglect. The Abbé carried his humor even further. In concluding notes he would add a pointed gibe; witty, daring, lascivious digs at men and institutions appeared repeatedly. They were not a rebuttal of scholarship but a shrewd lure for purchasers who usually avoided anything learned. He attempted to popularize the preface in the same fashion. Gone was a straightforward statement of facts, and in the *Marot* he presented a dialogue between friends which revealed a tremendous amount of pertinent information. It was, indeed, a sugar-coated offering, similar to our modern popular biographies. By such methods he sought to bridge the enormous gap between the scholarly and the popular work. He succeeded to some extent, for his books sold well, but he never reconciled these extremes, nor did he turn the critical edition into a best seller.

Though there is much in Abbé Lenglet's work which is good, there is also a great deal which is bad. It has since been the task of two centuries to choose by trial and error the essentials of a

[28] The *Méthode*, 1729, the *Marot*, the *Régnier*, and the *Lactantius* are excellent examples of the extent to which aesthetic printing was carried in the larger tomes. Among the octavos and the duodecimos the works of Pierre de l'Estoile and the *Arrêts* do not lag far behind. The *Roman de la Rose* was well executed, but the risk attendant upon publishing such an erudite volume did not warrant a very heavy investment.

[29] *Arrêts*, p. xxv. These words were inserted without quotation marks into a biobibliography compiled by Père Niceron and reprinted by the Abbé.

critical edition. His procedures in the collation of texts, internal criticism, variants, documentation, and annotation have become common. He was the first to stress the purely literary uses of paleography and diplomatics. His plan of glossaries is now almost universal. Although his handling of the preface has been greatly altered, its material content has remained almost unchanged. Unfortunately, the profit motive and popular appeal have been discarded to such an extent that truly fine craftsmanship in a simple definitive text is now almost unknown. In the end, however, the unified technical framework of criticism which has made possible the scholarliness of the volumes of learned societies remains today practically as he developed it.[30]

More precisely, the extent of our debt to Nicolas Lenglet du Fresnoy stands revealed by these very editions. The life and the value of a scholarly work are variable. It endures until something new is discovered; then it is forgotten, to be resurrected by antiquaries. The *Comines* of 1747 is still read today, even though its text was deemed only mediocre by the critical standards of 1924.[31] In other words, one hundred and eighty years of progressive textual criticism have not thrown the results of the Abbé's travail into discard.

To this laborious editor belongs the honor of having drawn the poet, Marot, from an oblivion of one hundred and thirty-eight years. Lenglet was the first to study his works in detail and to return to him his rightful glory. That edition appeared in 1731, and it was not actually superseded until 1911.[32] Even after so long and so useful a life, it is still in demand.

At present, shortly after the two-hundredth anniversary of Abbé Lenglet's edition of the *Roman de la Rose*, it is fitting to render him

[30] To discuss the sequence by which Lenglet's standards became the accepted norm would lead this article far astray. He did not conquer without a battle. For a decade he fought the Journalists of *Trévoux*, fending off at the same time spiteful thrusts from Abbé Desfontaines, J.-B. Rousseau, and Brossette. Hence each of the Abbé's successive editions is a strong restatement of his ideals. On the other hand, Gouget, d'Artigny, d'Argens, Secousse, Lecluse, Michault, and many others adopted his methods bodily. Furthermore, Lenglet became the editorial adviser to Rollin, and, which was more important, to the elder and younger de Bures. His influence is distinctly evident in their bibliographies and critical editions until the period of the Revolution.

[31] Calmette, *op. cit.*, p. xxvi.

[32] Guiffrey, Georges, ed., *Œuvres de Clément Marot* (Paris: Schemit, 1911), 1 : ix–x.

all the homage which is his due. Solely to him are we indebted for arousing interest in this medieval masterpiece. He awoke it from a slumber of two hundred years, swept away Marot's changes, established the text, and marked the path for its future critical study. Our knowledge of that poem today is the greatest possible tribute to his editorial perspicacity and genius.

Whether or not one realizes it, every editor and student of an old French historical or literary text owes profound gratitude to Lenglet du Fresnoy for having brought order and honor to their professional methods. He succeeded because he was industrious, accurate, and impartial, because he was sincere in his desire to benefit the public. As a result, he reaped neither wealth nor great fame, only spiritual contentment. In his own words, "It is a sweet consolation for a man to be able to say to himself, 'I can spread in the world of letters a good which is unknown and unexpected.'" [33]

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[33] *PH*, 1:2.

INVESTIGATING VOWEL DURATION IN FRENCH

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TO ANYONE who has some knowledge of experimental phonetics investigating the duration of sounds of speech seems a very easy task. Sounds can be recorded by various devices in use today and measured to hundredths or thousandths of a second. As compared with the study of pitch or of intensity or, especially, of quality, it looks simple. Yet if we examine a bibliography of experimental investigations in phonetics we are surprised by the relative scarcity of studies about quantity and also by the little that is known about it.

Taking, for instance, the French vocalic sounds, we find that their durations are mostly qualified by the adjectives "long" and "short" and that only the best authorities on French phonetics dare to use such terms as "a little longer" and "a little shorter," which are likewise vague and relative. What is known about "absolute quantity" of French vowels? Should one have need of measurements showing in hundredths or thousandths of a second duration of a certain vowel sound under predetermined conditions, such as the position in a rhythmical group or the influence of preceding and following sounds, he would not be able to find them anywhere.

Such statistics would be of the greatest interest to the linguist as well as to the teacher and would throw new light on the rôle of vowel duration in the phonetics of the French language. Having recently completed a study on the length of the French *E*-sounds,[1] which is to be published later as part of a general investigation of vowel duration in French, I am going to present here the problems I encountered in preparation for that work. This concerns purely the method of my investigation and how I was led to adopt it.

There are two ways to proceed: one is to deal with a single vocalic sound at a time and to study it under all possible conditions, stressed,

[1] Phonetic symbols in this paper are those of the International Phonetic Association. In addition, *E* means firm *E*, including all shades of timbre from e to ɛ.

unstressed, before each of the different consonants, etc.; the other is to study at one time all the vocalic sounds under the same condition, for instance, to take every one of the French vowels in tonic position before *s* previous to studying them in the same position before *z*, *d*, *m*, *r*, etc. I chose the first alternative mainly because it furnishes more rapidly results of a general character. For example, a tonic *E* before *r* averages nearly three times the duration of an atonic *E* before the same consonant. Also, a similar proportion exists when a comparison is made of tonic *E* before *r* and before *t*. But such great variations of length are never found on comparing different vowels under the same conditions, and if these conditions change, all the vowels show the same tendency of lengthening or shortening. In other words, the difference of duration between two vowels must not be accounted for mainly by their difference in quality (*timbre*). Therefore, after the complete investigation of a single vowel, one may formulate phonetic laws which will be true for all vowels. If one undertakes to study all the vocalic sounds at once, no generalization can be made before everything is finished, since the laws applying to one condition do not apply to another.

In selecting the first vowel to investigate I felt that the most instructive as regards duration was the open *E* of *clair*, *sec*. In such closed syllables the tonic *E* has, according to everyone, the open timbre. But in an open syllable, the pronunciation of tonic *E*, in such spellings as *ais*, *ait*, *et*, is subject to great diversity of opinion. While some insist on an open *E* and others on a close *E*, M. Fouché explains it as being in a state of evolution caused by the law of position. He says that the final *E* of *ai*, *et*, *êt* is progressing toward close *E*. "It has not yet succeeded in becoming so, but it is midway in its course, and in order to define it in a rather precise way we shall say that it is a middle *E*, intermediary between close *E* and open *E*, perhaps closer to the latter."[2]

For the pronunciation of atonic *E*, also, diversity of opinion exists. Rousselot's way of distinguishing three shades of *E* (open, close, and middle) constitutes one extreme,[3] whereas the other is ex-

[2] Fouché, P., "L'Evolution phonétique du français," *Où en sont les études de français* (Paris, 1935), p. 47.

[3] Rousselot, P. J., et Laclotte, F., *Précis de prononciation française* (Paris, 1927), p. 29: "Les voyelles orales peuvent se ramener à sept: a, e, i, eu, u, o, ou. Chacune de ces voyelles possède plusieurs nuances dont trois sont très nettes pour a, e, eu, o, deux seulement pour i, u, ou. Nous avons, pour le premier

pressed by M. Grammont, who denies the existence of a middle quality.[4]

Thus I found it necessary to include in the same study close *E* and open *E*, and I undertook to investigate the duration of all *E*-sounds from the most open to the most close. Then followed the problem of choosing and organizing the word material to be registered on the kymograph.

Vowel duration, in order to be of real interest to the phonetician or the teacher, must be that of actual speech. There must be nothing artificial about it. I was determined not to depart from that principle. Therefore I refused to consider the use of series of meaningless monosyllables, such as tɛp, tɛt, tɛk, tɛd, tɛg, tɛf, tɛs, tɛʃ, although that would have greatly simplified the task. It was certainly necessary to use *words*, so that I was tempted to replace each of the meaningless monosyllables by a monosyllabic word, for instance: *cep, dette, sec, Thèbes, cède, baigne, nef, caisse, sèche,* etc. But a most serious problem stopped me. Would the vowel duration in them be the same when pronounced alone as when pronounced in a sentence? Some aspects of that problem had been investigated by M. Grégoire in 1899.[5] Knowing from previous research the duration of vowel *â* in *pâte* (27), *pâté* (21), *pâtissier* (14), *pâtisserie* (12) when pronounced by themselves, he put those same words in the body of sentences, *dans le corps du discours*, such as: *Dans sa pâtisserie, le pâtissier fait des pâtés; Le pâtissier fait ses pâtés de pâte douce.* The words analyzed were in three groups: monosyllabic, dissyllabic, and polysyllabic. He found that monosyllabic words lost most in vowel duration, dissyllables less, and polysyllables very little. His findings indicate that the shorter the isolated word the more its vowel duration differs from that of the word in a sentence. According to this, the isolated monosyllable is the worst type of material to use, and it seems safer to use no isolated word at all. Furthermore, I noticed that the sentences of M. Grégoire quoted above made possible only a study of syllables *inside* the sentence or the rhythmical group. Evidently that

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groupe, une voyelle ouverte, une voyelle moyenne, et une voyelle fermée; pour le second, la voyelle ouverte manque."

[4] Grammont, M., *Traité pratique de prononciation française* (Paris, 1934), p. 5: "La prononciation française se distingue de la plupart des autres par sa netteté: les voyelles sont toutes bien timbrées, même en syllabe inaccentuée, et il n'y a pas de voyelles moyennes ou indécises."

[5] Grégoire, A., "Variations de durée de la syllabe française," *La Parole*, I, 418.

was what he meant by *dans le corps du discours*. Therefore his comparison of isolated words with words in the sentence concerned only atonic and semitonic syllables. As for tonic syllables, he gave his results in another part of the same article, but simply by a comparison of isolated words of a different number of syllables, such as *traité* and *maltraité*. Although he concluded that the tonic syllable "seems to be independent of the syllables which precede it," I could not use his results because he had not compared the isolated word with the word in a sentence.

All I knew definitely was that neither in the atonic nor in the semitonic syllables could I use isolated words to study vowel duration. Since tonic and semitonic syllables entered into my investigation, I decided not to use any isolated words at all, but to study *sentences* exclusively. Later in the course of my research I found that I had done the correct thing, for not only the atonic and the semitonic, but also the tonic, syllables had longer vowels in an isolated word than in a sentence. A comparison of one hundred and eighty-eight words showed an average difference of from 10 to 25 per cent, although the impression of the speaker was that he had pronounced the isolated words exactly at the same rate as when they were in sentences.

Another important reason for using sentences rather than isolated words became evident later when study of vowel duration in isolated words showed great irregularity as compared with the words in a sentence. A good example is the word *neige*, which, recorded four times in the group *un océan de neige*, at intervals of several days, had tonic vowel durations of 40, 40, 43, and 46 hundredths of a second, whereas the recordings of the isolated word gave 38, 47, 50, and 58.

Finally, is it not evident that the word can have its natural expression *in the sentence only* and that, no matter how hard one tries, it is impossible to record isolated words in series and to give them their full meaning? At the same time there is danger in recording one word after another in series. A certain amount of rhythm is bound to appear, with a tendency to harmonize all durations to one another.

Now before choosing the word material, it was necessary to determine the mechanical influences under which the duration of an *E* might vary. They include:

(*a*) The accent. *E* is tonic in the last syllable of a rhythmical group; semitonic in the last syllable of a major word which does not end a rhythmical group; atonic in all other cases. Examples of all three accents are shown in a sentence like *Vous l'avez bien aidé.*

(*b*) The type of syllable. It may be open, as are both syllables in *aidé,* or closed, as in *faible.*

(*c*) The consonants that follow. They must include all single consonants (*caisse, père,* etc.) and all groups of consonants, of which there are three kinds: groups beginning with a liquid (*perte*), groups ending with a liquid (*faible*), and groups without liquids (*secte*).

(*d*) The consonants that precede (*père, serre,* etc.). (The results showed that their influence should not be taken into account.)

(*e*) The vowels that follow in the next syllable. This influence is known as vocalic harmonization.

(*f*) The orthography of the *E.*

(*g*) The timbre of the *E.*

A total of three hundred and thirteen well-chosen words were sufficient to include all the preceding mechanical influences.

For a while I had an impression that I should also study the influence on atonic *E* of the distance of the tonic syllable of the word or the rhythmical group from it. The fact that the work of Menzerath and de Oleza, *Spanische Lautdauer,*[6] investigates the duration of Spanish sounds mainly from that viewpoint caused me to consider the question very seriously. I finally rejected it, basing my decision upon the following considerations.

Spanish has a much more pronounced *accent d'intensité* than French. That accent can be found on almost any syllable from the first to the last. Its place greatly influences the surrounding syllables. Spanish is a language spoken with relaxed muscles — comparable in this respect to English — which means that it shows different degrees of weakness in the weak syllables. It presented a most interesting field for investigation, and possibly the best angle for the study of Spanish sound duration. But is there a similar condition in French? French tonic accent is weak by comparison with Spanish. The weaker the tonic, the stronger the atonic by comparison. The accent is always on the same syllable, the last. Modern

[6] Menzerath, P., und de Oleza, J. M., *Spanische Lautdauer* (Leipzig, 1928).

French is a language spoken with tense muscles, which means that it does not favor grouping of syllables.

After a study of intensity and duration in the word *épouvantable* M. Grammont concludes that, although the intensity increases rapidly from the first to the last syllable, "the durations of the first three vowels are durations of brief vowels and are more or less even." [7]

M. Fouché seems to be of the same opinion as M. Grammont. "There is only one tonic accent, on the last syllable," he says about isolated words pronounced without *accent d'insistance*.[8] This makes it clear that he does not admit the existence of any secondary accent. I therefore accepted the principle that duration of the atonic firm vowels of a word was not sufficiently influenced by their place in the word or by their distance from the tonic to warrant taking that influence into consideration.

The next problem was to decide upon a type of subject matter to include the words. Having strongly in mind the representation of actual speech, I naturally decided to make up a text in the form of a story. But I met two difficulties: the large number of words to be put in tonic position (200 out of 313) and the lack of logical connection between them. Before I could have made use of all the words, my text would have been too long for kymograph recording. Hence I abandoned the composition of a connected text and decided to include my words in independent sentences of nearly the same length. I constructed sentences of about ten syllables which seemed easy to pronounce without pause. But when the subject pronounced them in succession before the mouthpiece, he often failed to say them in a single rhythmical group, and I found that the conclusions of Roudet [9] on the average length of rhythmical groups were quite correct. Seventy per cent of his sentences are from three to seven syllables long. I built all my sentences within those limits. A total of one hundred and eighty-eight was sufficient to include all the words in their proper positions, most sentences making use of two words. The following are typical examples: "Vois comme il se dépêche"; "Ce pêcheur est à son *aise*"; "Un Auvergnat se reconnaît."

[7] Grammont, M., *op. cit.*, p. 139.
[8] Fouché, P., "La Prononciation actuelle du français," *op. cit.*, p. 28.
[9] Roudet, L., *Eléments de phonétique générale* (Paris, 1910), p. 238.

Now it remained to choose a type of speech for recording. I have previously mentioned that I considered the "mechanical" influences on the vowel. They are the only ones that always act; therefore they are the first ones to be determined. The other influences might be called "expressive," as contrasted with mechanical. They are innumerable and include intonation, emphasis, rate of speech, which are means of expression for sentiments, passions, emotions, etc. I had to eliminate them until the mechanical influences were sufficiently known. Consequently I confined the intonation of the sentence to that of ordinary enunciation, avoiding at the same time any *accent d'insistance,* and I chose the rate of speech of rather careful conversation as conservative enough and yet realistic.

It is not within the scope of this paper to enter into a discussion of the technical problems of recording the measurement of vowel length. However, it is necessary to state that the same person was used in all the recordings. It remains to be seen in what measure other people's pronunciation may differ from that of my subject. Out of ten series of recordings five were definitely accepted because they were the only ones sufficiently similar to one another in respect to rate of speech. Since each influence was represented by a number of words ranging from one to four, it had from five to twenty readings. The separation of sounds was facilitated by the use of a new device of my own for recording the movements of the lower jaw. It was among five simultaneous tracings, one recording the nasal sounds and three the oral sounds. Synchronization of those lines was obtained by a mold very similar to the one Menzerath used in his study of Spanish sounds,[10] except that the material was transparent celluloid.

Finally some sentences were recorded as part of a connected text in order to find for what rate of speech the results of my work were valid and to what extent sentences, when enunciated separately, corresponded to the same sentences in the course of actual speech.

SUMMARY

Investigation of vowel duration in French should be started with a complete study of a single vowel, but include every timbre of that vowel. The vowels must be not in isolated words, but in sentences, the most practical type consisting of rhythmical groups of

[10] Menzerath und de Oleza, *op. cit.*, p. 32.

from three to seven syllables, pronounced with ordinary enunciation, free from *accent d'insistance* and at the rate of careful conversation. All expressive influences should be eliminated at the first. The principal mechanical influences on vowel duration include the accent and the surrounding sounds, but not the distance from the tonic syllable.

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SOME NOTICES OF "EMPATHY" BEFORE LIPPS

CLARENCE DEWITT THORPE

IN HIS *Coleridge on the Imagination*[1] I. A. Richards quotes Coleridge as saying: "One travels along with the lines of a mountain. Years ago I wanted to make Wordsworth sensible of this." Mr. Richards inserts after this in parenthesis: "1804, Lipps' doctrine of empathy came in the eighties." [2] Coleridge's account of empathic response, in which the sentences mentioned by Richards are embedded, is remarkably comprehensive. It occurs in a description of the Mediterranean and the effects of the sea on the mind.

> A brisk gale and the foam that peopled the alive sea, most interestingly combined with the number of white sea-gulls, that, repeatedly, it seemed as if the foam-spit had taken life and wing and flown up. . . . O that sky, that soft, blue, mighty arch resting on the mountain or solid sea-like plain — what an awful omneity in unity! I know no other perfect union of the sublime with the beautiful, so that they should be felt, that is, at the same minute, though by different faculties, and yet, each faculty be predisposed, by itself, to receive the specific modifications from the other. To the eye it is an inverted goblet. . . . To the mind it is immensity; but even the eye feels as if it were [able] to look through with [a] dim sense of the non-resistance — it is not exactly the feeling given to the organ by solid and limited things, [but] the eye feels that the limitation is in its own power, not in the object.

Here follow the sentences quoted by Richards, supplemented by further illustration:

> Would I repose, my soul lies and is quiet upon the broad level vale. Would it act? it darts up into the mountain top like a kite and like a chamois-goat runs along a ridge — or like a boy that makes sport — of running along a wall or a narrow fence!

Coleridge ascribes this effect to a general psychological phenomenon:

> One of the most noticeable and fruitful facts in psychology is the modification of the same feeling by difference of form. The Heaven lifts up my soul, the sight of the ocean seems to widen it. We feel the same force at work, but the difference, whether in mind or body, that we should feel in actual traveling

[1] New York: Harcourt, Brace and Company, 1935. [2] P. 68.

horizontally or in direct *ascent*, that we feel in *fancy*. For what are our feelings of this kind but a motion imagined, [together] with the feelings that would accompany that motion, [but] less distinguished, more blended, more rapid, more confused, and thereby, co-adunated.[3]

Although he has given no special name to the experiences described, Coleridge shows here how far he had advanced in the theory of physioemotional response which later writers were to define as *Einfühlung*.

Like so many other "new" theories, the psychological phenomena accounted for by the doctrine of "empathy" or *Einfühlung* had been observed and recorded long before either Coleridge or Lipps, or even Lotze, who is sometimes credited with its initial formulation, had noted them.[4] The basic postulate of the theory that the nervous system of the percipient experiences from certain natural or artistic forms actual physiological tensions, endeavors, and expansions — or their opposites, laxness and repose — is implicit in isolated passages in Dennis, Addison, John Baillie, Hume, Gerard, Kames, and Reynolds, and it is suggested in the writings of Herder and Kant. It is of interest that most of these early recognitions of empathic response occur in descriptions of sensations in the presence of objects of grandeur or sublimity. They may be associated with the growing concern of eighteenth-century critics with the nature and causes of aesthetic pleasure, and, in general, appear as tentative explanations of mental phenomena that had previously passed unnoticed. Thus John Dennis, in his notable letter describing his sensations on crossing the Alps, dated 1688 and published in 1692, declares: "'Tis . . . impossible to set a mountain before your eyes, that is inaccessible almost to the sight, and *wearies the very eye to climb it.*" [5] A few years later Addison, defining the emotion of sublimity, writes: "Our Imagi-

[3] *Anima Poetae*, ed. by E. H. Coleridge (London: William Heinemann, 1895), pp. 100–102.

[4] Theodor Lipps' *Raumaesthetik und geometrisch-optische Täuschungen*, in which his *Einfühlung* theory is stated, was published in Munich in 1897; Hermann Lotze's *Geschichte der Aesthetik in Deutschland*, containing the basic ideas to be found in Lipps, appeared in 1868, also in Munich. H. S. Langfeld, *The Aesthetic Attitude* (New York: Harcourt, Brace and Company, 1920), has outlined Lotze's contribution to *Einfühlung*, with due notice of Herder's faint anticipation of the theory.

[5] Dennis, John, *Miscellanies in Prose and Verse* (London, 1692), p. 133. Shaftesbury's recognition of the principle is less definite, but it is none the less suggestive of the essential experience:

"'You see then a certain little gate, and a way that leads to that gate that

nation loves to be filled with an object, or to grasp at anything that is too big for its Capacity." [6] The idea of physiological reaction suggested here becomes more explicit as he proceeds:

> The Mind of Man naturally hates everything that looks like a Restraint upon it, and is apt to fancy itself under a sort of Confinement, when the Sight is pent up in a narrow Compass, and shortened on every side by the Neighbourhood of Walls or Mountains. On the contrary, a spacious Horizon is an Image of Liberty, where the Eye has room to range abroad, to expatiate at large on the Immensity of its Views, and to lose itself amidst the Variety of Objects that offer themselves to its Observation.[7]

The physical sense of tautness and restraint when one is in canyons and mountain passes is here admirably expressed, as are the release and the buoyancy one feels on open mountain heights, on a wide plain, or on the deck of an ocean liner. Obviously, it is the mind, or better yet the whole man, not the eye, that experiences a sensation of large and free motion, as if one were in truth ranging about in immense spaces.

In further exposition of sublimity Addison continually uses phrases that suggest physioemotional response. "Nothing is more pleasant to the Fancy," he writes, "than to enlarge itself, by Degrees, in its Contemplation of the various Proportions which its several Objects bear to each other." Of all writers, he explains, none are better fitted to "gratifie and *enlarge* the Imagination than the Authors of the New Philosophy." In contemplating the infinitudes of the solar universe "our Imagination finds its Capacity filled with so immense a Prospect, and puts itself upon the Stretch to comprehend it." [8]

> But if we yet rise higher, and consider the fixt Stars as so many vast Oceans of Flame, that are each of them attended with a different Sett of Planets . . . we are lost in such a Labarinth of Suns and Worlds . . . .[9]

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is not much crowded and where very few are passing, it appears to be very rough and rocky, and passable with great difficulty.'

"'I do,' said I.

"'Then there appears to be a high hill, whose ascent is extremely narrow with deep precipices on both sides of it.'

"'I see it.'

"'This therefore,' said he, 'is the way that leads to true learning.'

"'Truly 'tis trouble even to look at.'" — "Picture of Cebes," *Second Characters*, 1712 (?), ed. by Benjamin Rand (Cambridge University Press, 1914), pp. 71–72.

[6] *The Spectator*, No. 412.

[7] *Ibid.*

[8] *Ibid.*, No. 420.

[9] *Ibid.*, No. 412.

It is clear that Addison is not at all concerned with a *theory* of empathy; it is equally clear, however, that, in his effort to define actual effects, he is giving us the thing itself without the name.

John Baillie, writing in 1747 on the sublime, again explains the effect of greatness in terms suggestive of empathic response. To Baillie, sublimity is an "exalted sensation" which arises when one is in the presence of large objects that affect him "with something which as it were extends his very Being, and expands it to a kind of Immensity." In further explanation he asserts: "That Object only can be justly called *sublime* which in some degree disposes the Mind to this *Enlargement* of itself, and gives her a lofty conception of her own Powers." Experience teaches us, continues Baillie, "that nothing produces this Elevation equal to large Prospects, vast extended Views, Mountains, the Heavens, and an Immense Ocean." These objects please, Baillie concludes, because their vastness arouses in the soul a "Consciousness of her own Vastness," than which nothing can be more delightful.[10] In this definition of the sublime as a specific subjective response Baillie comes very close indeed to a description of empathy.

Quite as much to the point, and with even more attention to psychological exposition, Hume had written in 1737, also with sublimity in mind, that,

> 'Tis evident that the mere view and contemplation of any greatness, whether successive or extended, enlarges the soul, and gives it a sensible delight and pleasure. A wide plain, the ocean, eternity, a succession of several ages; all these are entertaining objects, and excel every thing, however beautiful, which accompanies not its beauty with a suitable greatness.[11]

Hume's general explanation of this phenomenon is that the soul takes pleasure in opposition:

> 'Tis a quality very observable in human nature, that any opposition, which does not entirely discourage and intimidate us, has rather a contrary effect, and inspires us with a more than ordinary grandeur and magnanimity. In collecting our force to overcome the opposition, we invigorate the soul, and give it an elevation with which otherwise it wou'd never have been acquainted. Compliance, by rendering our strength useless, makes us insensible of it; but opposition awakens and employs it.

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[10] *An Essay on the Sublime* (London, 1747), pp. 4–7. Professor Samuel Monk first called my attention to the implications for empathy in this passage. See *The Sublime in XVIII Century England* (New York, 1935), p. 73.

[11] Hume, Alexander, *A Treatise on Human Nature*, ed. by L. A. Selby-Bigge (Oxford: At the Clarendon Press, 1888), Book II, Part 3, Sec. 8, p. 432.

Such principles affect the imagination as well as the passions, Hume goes on to say:

To be convinc'd of this we need only consider the influence of *heights* and *depths* on that faculty. Any great elevation of place communicates a kind of pride or sublimity of imagination, and gives a fancy'd superiority over those that lie below; and *vice versa*, a sublime and strong imagination conveys the idea of ascent and elevation. Hence it proceeds, that we associate, in a manner, the idea of whatever is good with that of height, and evil with lowness. Heaven is supposed to be above, and hell below. A noble genius is call'd an elevate and sublime one.

Such methods of thinking, Hume asserts, are of deep importance, and he proceeds to show their fundamental relationship to common experience:

'Tis evident to common sense, as well as philosophy, that there is no natural nor essential difference betwixt high and low, and that this distinction arises only from the gravitation of matter, which produces a motion from the one to the other. The very same direction, which in this part of the globe is call'd *ascent*, is denominated *descent* in our antipodes; which can proceed from nothing but the contrary tendency of bodies. Now 'tis certain, that the tendency of bodies, continually operating upon our senses, must produce, from custom, a like tendency in the fancy, and that when we consider any object situated in an ascent, the idea of its weight gives us a propensity to transport it from the place, in which it is situated, to the place immediately below it, and so on, till we come to the ground, which equally stops the body and our imagination. For a like reason we feel a difficulty in mounting, and pass not without a kind of reluctance from the inferior to that which is situated above it; as if our ideas acquir'd a kind of gravity from their objects.[12]

Here are the facts of empathy in a nutshell, and it appears that Hume is much more conscious of announcing and defending a theory than was Addison or Baillie.

Alexander Gerard seems likewise aware of the theoretical implications of what he is saying when he describes our psychophysiological responses to great and dynamic objects. The similarity of Gerard's ideas to Addison's and to Hume's is striking:

When a large object is presented, the mind expands itself to the extent of that object, and is filled with one grand sensation, which, totally possessing it, compasses it into a solemn sedateness, and strikes it with deep silent wonder and admiration: it finds such a difficulty in spreading itself to the dimensions

[12] *Ibid.*, pp. 433–434. Hume is obviously writing in full awareness of the physiological reaction in the presence of elevated or extended objects which is described by Vernon Lee, in his exposition of empathy, as "another of those various mergings of the activities of the perceiving subject with the qualities of the perceived object." — *The Beautiful* (Cambridge University Press, 1913), p. 67.

of its object, as enlivens and invigorates its frame: and having overcome the opposition which this occasions, it sometimes imagines itself present in every part of the scene which it contemplates; and from the sense of this immensity, feels a noble pride, and entertains a lofty conception of its capacity.[13]

Lord Kames also deliberately adumbrates a theory, though still without giving it a name, in his explanation of the effects of grandeur:

A great object makes the spectator endeavour to enlarge his bulk: which is remarkable in plain people who give way to nature without reserve; in describing a great object, they naturally expand themselves by drawing in air with all their force. An elevated object produces a different expression: it makes the spectator stretch upward, and stand a-tiptoe.[14]

Similarly acute is Kames' observation on the cause of our response to the force of a moving body:

All we can say is, that the emotion raised by a moving body, resembling its cause, is felt as if the mind were carried along: the emotion raised by force exerted, resembling also its cause, is felt as if force were exerted within the mind.[15]

Sir Joshua Reynolds, whose brief excursions into the field of psychological analysis are of great value, furnishes another eighteenth-century description of *Einfühlung:*

This appearance of ease and facility may be called the Grace or Genius of the mechanical or executive part of the art. There is undoubtedly something fascinating in seeing that done with careless ease, which others do with laborious difficulty: the spectator unavoidably, by a kind of natural instinct, feels that general animation with which the hand of the Artist seems to be inspired.[16]

Whereas the other writers I have cited refer to reactions to nature, Reynolds is here noting response to art. His comment may be compared with Langfeld's generalization on our feeling of force and movement in painting:

[13] *Essay on Taste* (Edinburgh, 1758), p. 12.

[14] Home, Henry (Lord Kames), "Grandeur and Sublimity," *Elements of Criticism* (Edinburgh: John Bell and William Creech, 1788), I: 211. This book was first published in 1761. Kames, as well as Gerard, shows evidence of recalling Addison's remarks on sublimity.

[15] The nearness of Kames and Gerard to the later theory can be better appreciated by quoting a few sentences from the exposition of Lipps: "A similar way of considering things can be noticed whenever we speak of a 'force' residing in an object; more clearly even whenever we realize a 'striving' or a 'tendency' in anything that happens, whenever we realize any 'doing' or 'being done to', any 'activity' or 'passivity'. All such vivifying of our surrounding realities comes about, and can come about only as we attribute to outer things our own feeling of force, our own activity and passivity." — *Op. cit.*, p. 6.

[16] In "Annotations" to William Mason's translation of *The Art of Painting* by Charles Alphonse Du Fresnoy (Dublin, 1783), p. 98, note xlvii.

In painting we have also strong sensations of power or of swift irresistible motion, according to the purpose of the artist, and the empathic participation is almost if not quite as complete as it is in statuary.[17]

Professor DeWitt Parker has pointed out that the general tendency of German Romantic aesthetics to emphasize the "expressive" in art and nature is in harmony with the *Einfühlung* theory.[18] Thus we find not only Herder but Kant referring to the exercise of energies of the mind in contemplating objects of aesthetic interest. Kant, particularly, deserves mention here as following in a general way the ideas announced by Addison, Gerard, and Kames. The mind responds to sublimity, says Kant, because of its natural susceptibility to certain ideas, a "moral feeling" which causes the reason to extend itself "in conformity with its own realm (the practical) and to make it look out into the infinite." [19] In astonishment created by great objects, he says again, we feel the might of the imagination "in combining with the mind's repose the mental movement thereby excited." [20] "Sublimity, therefore, does not reside in anything of nature, but only in our mind . . . . Everything that excites this feeling in us, e.g. the might of nature which calls forth our forces, is called then (although improperly) sublime." [21] Kant definitely ascribes the mental movement of the sublime to the imagination,[22]

[17] Langfeld, *op. cit.*, pp. 147–148.

[18] In unpublished lectures on aesthetics. In his published works Professor Parker has done much to clarify and apply the empathic principle. Explaining our responses to a statue of a runner ready to start or to such a picture as "The Laughing Cavalier," he writes: "Yet in both cases I may feel the emotions as also my own — as if I too were about to run or were laughing. And the projection of the idea of the self will occur most readily if I am myself a runner or a jolly person. In both instances, moreover, the process will be mediated by impulses to movements that are the normal accompaniments of the emotions in question. If I observe myself carefully, I may find that my own chest is tending to swell and my limbs to tighten, in imitation of the runner's, or my pupils to dilate and the muscles of my face to wrinkle and to part in imitation of the Dutchman's." Professor Parker explains that the psychology of this process rests upon the principle of association. There is a "connection between the sight of a movement and sensations attendant upon movement, and further, a connection between some of these movements, namely, the expressive movements, and the emotions which they express." — *The Principles of Aesthetics* (Boston and New York: Silver, Burdett and Company, 1920), pp. 64–65.

[19] *Critique of Judgment* (1790), tr. by J. H. Bernard (London, 1914), Part I, Division i, No. 29.

[20] *Ibid.*

[21] *Ibid.*, No. 28. For the idea that sublimity resides only in the mind see also *ibid.*, Nos. 23, 25, 30.

[22] *Ibid.*, Nos. 24, 27.

and he speaks of this as an "effort towards comprehension," [23] as a "power," a "grasp," an "extension to the greatness of the world," [24] a "striving toward infinite progress." [25] He writes, too, of the pleasure of sublimity as being produced by a "feeling of a momentary checking of vital powers and a consequent stronger outflow of them"; [26] of the mind in the experience of sublimity as striving to surpass its maximum and sinking back into itself; [27] and of the imagination in this experience as finding the "transcendent" toward which it is impelled "like an abyss in which it fears to lose itself." [28] It is true that Kant's objective is to define the feeling of the sublime in terms of transcendental not of physiological thought; yet much of his description of the actual experience of sublimity tends toward the physical, a fact that is reinforced when we remember that with Kant the imagination is closely related to sense, is, indeed, "our greatest faculty of sense." [29] Add to this the frequent insistence by Kant that we must regard the sublime as strictly within ourselves, merely as an "attitude" or "a state of mind," as a movement of imagination through which the forces of great objects and infinite spaces are expressed, and we readily perceive the materials and implications for the empathic theory of response.

The examples I have presented of early descriptions of the phenomena underlying the theory of *Einfühlung* have been encountered in almost casual reading. There are undoubtedly many more. They serve not only to corroborate the empathic doctrine, as having its basis in general human experiences, but to illustrate the fact that psychological "discoveries" are frequently only a more conscious noting and elaboration of what careful observers of mental phenomena have already perceived and expressed, only in different terms. The circumstance that the majority of the cases I have found are associated with attempts to explain the sensation of sublimity is worthy of more than passing notice. It shows that the acceptance of sublimity as a valid aesthetic emotion not only widened

[23] *Critique of Judgment* (1790), tr. by J. H. Bernard (London, 1914), Part I, Division i, No. 26.

[24] *Ibid.*, No. 25.

[25] *Ibid.*

[26] *Ibid.*, No. 23.

[27] *Ibid.*, No. 26.

[28] *Ibid.*, No. 27.

[29] *Ibid.* Conceding some truth to Burke's theory, Kant writes: "And so, as Epicurus maintained, all gratification or grief may ultimately be corporeal, whether it arises from the representations of the Imagination or the Understanding; because life without a feeling of bodily organs would be merely a consciousness of existence." — *Ibid.*, No. 29.

the range of aesthetic interests to include the vast and wild and irregular, but it enlarged the field of aesthetic speculation, the recognition of new sources of imaginative pleasure requiring new explanations and new terms by which to describe them. All of which in turn belongs to the broadened stream of psychological inquiry into the behavior of the mind in aesthetic processes which was one of the distinctive marks of the evolution of Romantic elements in eighteenth-century criticism. In Kames, Reynolds, and Coleridge we find applications extending beyond the sphere of the sublime to include some of the more varied phases of response recognized in later expositions of empathy.

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THE NATURE OF THE INDO-GERMANIC SIBILANT

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IN THE case of none of the hypothetical phonemes of Indo-Germanic is there greater disagreement among scholars than in that of the sibilants. Brugmann is perhaps the least open to criticism in his guarded statement: "Ein tonloser *s*-Laut, dessen Artikulationsstelle sich nicht genau feststellen lässt." [1]

Hirt lists the Idg. sibilant simply as a spirant; but since he declares that Idg. *z* is French *z*, he no doubt means that *s* also is French *s*, i.e. a low dental.[2] He admits the possibility of the existence of another *s* in Indo-Germanic, and quotes in support a list of seventeen Greek words with initial sigma. He suggests, however, that these may be loan words or may be due to attrition of original consonantal combinations. He also scouts the existence of *þ* and *ð* in Idg.[3]

Kieckers should represent the consensus of opinion of modern times, but he contents himself with the statement that Idg. contained the spirants *s, sh; z, zh; þ, þh; ð, ðh.* "Von diesen kommen *sh, zh, þ, þh, ð, ðh* nur in bestimmten Stellungen vor; *z* nur in der Umgebung von (meist vor) stimmhaften Verschlusslauten." [4] There is no further information about the articulation of these sibilants.

The most generous scholar of all is Bartholomae,[5] who attributes to Idg. no fewer than ten sibilants: *þ, ð, s, sh, z, zh, š, šh, ž, žh.* Of these only six agree with Kieckers' list of eight.

Bartholomae, however, immediately checks this exuberance of sibilants in his own linguistic field, since he states in the following

[1] Brugmann, K., *Grundriss der vergleichenden Grammatik der indogermanischen Sprachen* (Strassburg, 1886), Vol. I, § 554, 1.

[2] Hirt, H., *Indogermanische Grammatik* (Heidelberg, 1921), Vol. I, § 177.

[3] *Ibid.*, p. 231.

[4] Kieckers, E., *Einführung in die indogermanische Sprachwissenschaft* (Munich, 1933), p. 69.

[5] Bartholomae, Ch., *Grundriss der iranischen Philologie* (Strassburg, 1904), Vol. I, § 37.

paragraph that, although the primitive Arian language made no change in these sounds, except that after *i*- and *u*-vowels *s* and *z* became the corresponding *š* and *ž*, in Indian both aspiration and voicing of sibilants were given up, the *s*-sounds became cerebral, *þ* became *t*, and *ð* became *d*. For Iranian also he posits sweeping changes: *þ* and *ð* became *s* and *z* respectively; the aspiration of sibilants was abandoned; *š* and *ž* stood firmly, while *s* and *z* remained unchanged only before a tenuis or *n* or after a *t* or a *d* (after *p* or *b* they became *š* and *ž*; under all other circumstances *s* became *h*).

Reichelt has the original of Kieckers' list. He remarks,[6] however, that the four elements of the *þ*-series occurred only after guttural consonants, and are preserved as *τ* in Greek, but as *s*, *sh*, *z*, *zh*, respectively, in Arian. Also the *s*-sounds become the corresponding palatal sibilants, *ś*, *śh*, *ź*, *źh*, in Arian after the vowels *i* or *u*, a liquid, or a guttural.

If we omit from consideration the development of the controversial marginal series (*þ*, etc.), we find the following standard theories for the representation of an Idg. sibilant (or sibilants) in the various historical languages:

In Sanskrit the Idg. sibilant usually remained as dental *s*, but after *i*, *u*, *r*, *k* it became the cerebral *ṣ*. In final position it became visarga. Sometimes it became palatal *ś* by assimilation, e.g. *śvašura* (ἔκυρος).

In Avestan the sibilant appears as *š* after *i*- and *u*-vowels, *p*, or *b*. If not so preceded it remained as *s* when it was immediately followed by a stop consonant or by *n*. Otherwise it became *h*. In Old Persian, however, a final *s* (not *š*) disappeared without trace.

In Armenian the sibilant disappeared everywhere except that before *t* or *χ*, in gemination, or after an original nasal it remained as *s*.[7]

In Slavic *s* generally remained as *s*, but after *i*, *u*, *r*, and *k* it became *χ*. *Si* became *š*.

In Baltic *s* remained as *s*, but the combination *rs* became *rš* in Lithuanian and *si* became *š* in Lettish.

[6] Reichelt, H., *Avestisches Elementarbuch* (Heidelberg, 1909), p. 51.

[7] Meillet, *Mémoires de la société de linguistique de Paris*, 9 (1895) : 151: "Au commencement de la syllabe *s* devient *h* en arménien de même qu'en iranien et en grec . . . mais après *r* on a *š*." He quotes only one word in support of this: *garšel* (cf. lit. *garszus* [?]), *kharšen*.

In Albanian original *s* is represented by *š*, *h*, *θ*, and *ǵ*, never by *s*. *S* occurs in the language as a development from Idg. *k* or *ti*.

In Celtic initial *s* before vowels or sonants was retained in Old Irish, but Welsh shows *h* here. It disappeared between vowels and between a vowel and a sonant. Final *s* also disappeared.[8]

In Greek the sibilant remained as sigma only when geminated, in final position, and before or after a stop consonant, if this combination was initial or medial between vowels. It disappeared when between consonants or between vowels.[9] It became the spiritus asper when initial before a vowel. A new Greek sigma developed from initial *tj*–, *tw*–, *t* + *u*–, and from medial *t* + *i*, *t* + *u*, *tj*, *tw*, *ts*, and by analogy.

In Latin and Umbrian the sibilant remains as *s*, but between vowels it appears as *r*; in Oscan it likewise remains as *s*, but between vowels it appears as *s* or *z*.

In Germanic also the sibilant is retained as *s*, but by Verner's law it becomes *z*, which further develops in West and North Germanic to *r*.

What sort of thing could the original Idg. sibilant have been? What was the pristine form of this phonetic Proteus that appears as almost everything in the way of a fricative from the interdental *þ* to the velar *ach*-Laut and even a glottal? Is it possible for us to determine on some strategically located central *s* that sent off colonies in every direction like the primitive Indo-Germanic race, and if so can we reach a conclusion more definite than Brugmann's "tonloser *s*-Laut, dessen Artikulationsstelle sich nicht genau feststellen lässt"? Is it possible that in the primeval tongue of our linguistic ancestors there were several sibilants?

If the first of these hypotheses is of any value, it is evidently from the centrally located cerebral that we should proceed: if we favor the second, we should endeavor to find confirmation in differing developments of the sibilants under identical conditions. I believe that a certain amount of direct evidence for a cerebral sibilant is afforded by Greek, Germanic, Sanskrit, and Slavic, and corroborative evidence by other written languages.

[8] Thurneysen, R., *Handbuch des Alt-Irischen* (Heidelberg, 1909), Vol. I, §§ 215–217.

[9] Hirt, H., *Handbuch der griechischen Laut- und Formenlehre* (Heidelberg, 1912), § 230.

When Greek was reduced to written form the current Semitic alphabet of the time was used to express the Greek sounds. This alphabet is preserved to us in its most ancient form in the inscription of the Moabite Stone from 890 B.C., that is, from a period antedating Homer. It contains four signs for sibilants, and the phonetic value of these is pretty well established. I was a dental voiced *s*, ⊞ a dental voiceless one. W is believed to have represented originally two sibilant sounds, the palatal voiceless spirant *š* and another sound so close as to be easily confused with it, *ç* or *ṣ*. In Hebrew this latter sound fell together qualitatively with the dental sibilant, samech, in the course of time, although it was still written (generally) with sin (shin), and the *sibboleth–šibboleth* of Judges xii.6 probably reflects the change.[10] The sin of Hebrew is, however, represented by shin in Arabic and vice versa, which is clear evidence that these sounds were very close to each other in ancient times. The Greeks may very well have found in the language of their Phoenician teachers the exact equivalent of the cerebral sigma of modern times; they certainly did find the near equivalent *š*.

The fourth sibilant of the Moabite Stone is the character sadhe (ϟ); it represented a voiceless cerebral (or alveolar) *s* with the peculiar Semitic retraction of the tongue which has given it the grammatical designation of *emphatic*.

On the ground of inscriptional alphabets, particularly that of Caere (Etruscan, as seen on the vase of Galassi), it is maintained that all the Semitic sibilants were taken into Greek. The Semitic letters, however, were at the same time numerical signs, and their use as such was quite as important as the phonetic one; hence the occurrence in the letter lists of purely mathematical signs with no regard to phonetic value is not surprising; indeed, this peculiarity is to be found even in the late Greek alphabet, where quoppa, digamma, and sampi occurred as numerals only.[11] The mere occurrence of all four Semitic signs here and there in Greek inscriptional alphabets does not prove that all four were ever used with distinct phonetic values.

We may disregard the zayin (zeta), which from the earliest times

[10] O'Leary, D. L. E., *Comparative Grammar of the Semitic Languages* (London, 1923), pp. 60–61.

[11] Wulfila's Gothic alphabet also has such numerical characters without phonetic value, for example, those for 90 and 900.

was probably used for a consonantal combination (*zd*, *dz*), since it was the only symbol available to the Greeks for a voiced sibilant or affricate. The question of the voiceless sibilant, however, is all-important. The undisputed facts of the case are the following:

(1) ⊞, which is clearly the Semitic samech, was never used, except as a numeral, until it was arbitrarily assigned the value of *ks* by a spelling reform movement.

(2) M is the exclusive form of the surd sibilant in the older inscriptions.

(3) Ϻ later entirely displaced M.

(4) No inscription uses more than a single character to represent the surd sibilant in Greek words.[12]

As to what was the origin of M scholars disagree, some asserting that it is only an inverted Semitic shin, others contending that it is from sadhe, for in the Caere vase the form occurs in the eighteenth place (Ϻ in the twentieth).[13] It is generally believed that Ϻ is the Semitic shin, because it is always found alphabetically after rho.

It is not necessary, however, to go into the merits of the arguments, for it appears plainly that the Greeks had only one surd sibilant and that whether sadhe or shin was the letter used, the sound

[12] There is, of course, disagreement among scholars who have expressed themselves on the Greek sibilant(s).

v. Gardthausen: Only one *s* in Greek; ⊞, M (ϻ), Ŧ are used only for combinations of *s*; M occurs as numeral (18) in old alphabets.

Kirchhoff: Greek had only one surd sibilant, which was at first designated by M, subsequently by Ϻ.

Larfield: Greek used ⊞, M, Ϻ beside one another, for it had three distinct sibilants. Ϻ was "rauher und dichter"; M was "einfacher und schärfer"; ⊞ was "sanfter."

Lagerkrantz: Greek had two surd sibilants, *s* and *š*, which fell together before Homer. M and Ϻ were nowhere in use beside each other.

[13] This is the principal ground for identifying M with sadhe. The inscription consists of a complete alphabet running about the base and a fragmentary Etruscan syllabary about the belly. It is a carelessly executed piece of work, for the syllabary has omissions and interlinear additions and a part of it is scratched over an underlying mistake. Significant facts are that the M and N have unique forms and that quoppa occurs in the syllabary, but not in the alphabet (the character ϻ stands where quoppa should be). The syllabary writes *si sa su se* with the Ϻ, and does not use M (ϻ) or ⊞ at all. Since the form ϻ does not occur elsewhere and stands here in the place of quoppa, it may be fairly doubted that it has anything to do with sadhe at all; it may be only an attempt to represent quoppa, and the alphabet and the syllabary may come from different persons.

could not have been a dental; otherwise the Semitic samech certainly would have been employed. It is interesting to note that the identical problem arose many centuries later when Hindoos began to write their language with Arabic letters; the Hindustani cerebral could not be indicated exactly by sin, shin, or sad, and this time also the choice fell on shin.

The Greek developments *tj* and *ti* to sigma also suggest a contemporary palatal or cerebral articulation.[14]

Of corroborative value for the cerebral pronunciation of the Greek sibilant is the interesting passage of Herodotus (1.139) which declares that all Persian proper names end in the letter which Dorians call san and Ionians call sigma: *τὰ οὐνόματά σφι ἔοντα ὅμοια τοῖσι σώμασι καὶ τῇ μεγαλοπρεπείᾳ τελευτῶσι πάντα ἐς τωυτὸ γράμμα, τὸ Δωριέες μὲν σὰν καλέουσι, Ἴωνες δὲ σίγμα.*[15]

Of course, final *–s* disappeared in Old Persian, but the *–š* persisted, so that Herodotus is here declaring the Greek sound the equivalent of a palatal *š*, an inaccuracy that is easily understood if he himself really pronounced a cerebral.

It seems to me that the cerebral best fits the epigraphic facts of ancient Greek, and there is in addition the supporting evidence of the modern Greek pronunciation, in which the sigma is a cerebral.

In Latin there was evidently no distinction felt between the native sibilant and the corresponding Greek sound. The Latins adopted the Greek symbol and never attempted any diacritical distinctions, although they were aware of phonetic differences where they existed, as in *p–φ*; *s–ζ*; *u–υ*; *t–θ*; *c–χ*.

Also a cerebral *ṣ* has been preserved in Castilian and Galician, a palatal in Portuguese.

We find that in Germanic Wulfila adopted the Latin *s* for his

[14] This observation I owe to my esteemed colleague, Dr. Hirsch Hootkins.

[15] The two names of the Greek phoneme are also a matter of debate. San is generally supposed to be a corruption of the Semitic shin, but sigma is puzzling. That it is a corruption of samech (samchad) is very improbable, and it seems equally far from shin and sadhe. It is to be noted, however, that both Ionians and Dorians used the character Ϟ, and we cannot be sure by what name the Phoenicians may have called their W, for the Aethiopic name is saut. Perhaps an original sim (cf. Coptic sima) may have been supplied with a terminal *–a* (sima), as in the case of alpha, beta, gamma, delta, etc., after which some analogy caused the intrusion of the *–g–*. Perhaps the extra *–g–* is a glide sound that resulted from rapid pronunciation of pi, rho, si(g)ma, tau. At any rate the name sigma does not afford clear proof that the phoneme was an emphatic or a dental *s*.

alphabet instead of the Greek C, but this was very probably to secure a clear distinction from the Ϛ and not because he noticed any difference in sibilants. Moreover, it is very probable that the Gothic *s* and *z* were cerebral themselves; indeed, that the Germanic *s* in general was cerebral, for Old High German long distinguished carefully its inherited Idg. *s* (written with the Latin character) from the dental sibilant resulting from the second sound shift. The Runic futhark also had a distinct sign for the *r* developing from *s*; it did not use the character for Idg. *r* to designate this new *r*, in either the longer or the shorter form, a fact which proves that the two must have been distinct in quality for centuries. Furthermore, in Old Norse the *r* resulting from *s* in accordance with Verner's law caused palatal umlaut of a preceding vowel, an effect that could not possibly be brought about by a low dental position.

In addition, certain developments in the later languages point to a cerebral quality of the Germanic *s* in general, e.g. that of *sk* in Continental Germanic to *š*, and that of *s* to *š* in the combinations *sm*, *sn*, *st*, *sp*, *rs* in South German. This change is readily explained as an application of ease in articulation if we start from a cerebral *ṣ*, but not so readily intelligible if we posit an original dental *s*; Italian, for example, has no tendency to change its *storia* to *štoria*.

A bit of corroborative evidence from ancient times is offered by Hungarian. This language took its phonetic symbols from the German of the thirteenth century. Its sibilants are two, the palatal surd and the low dental surd. For the palatal the Hungarians chose the German symbol *s*, and for the dental they used *sz*, again a confusion of cerebral and palatal such as we have noted before.

Lastly the modern *s* of all branches of Germanic is in general alveolar rather than dental.

In Sanskrit, of course, we have the three sibilants *š*, *ṣ*, and *s*, and this is the only language of our family in which the natives have made a clear distinction of a cerebral by a separate phonetic character. But not only does Sanskrit have a separate sign for the cerebral *ṣ*; it has distinct characters for the entire cerebral series of stops, the nasal, and the lateral. According to Panini, the *r* and *ṛ* also belong here, and they are pronounced as cerebrals by the pundits of today.

It is the usual explanation of this unique but complete series of Sanskrit cerebrals that the stops and the nasal are always the result

of the assimilation of true dentals to the cerebral sibilant, that they are only developments within Sanskrit itself and cannot possibly be a survival from Idg. That is not all; the very *ṣ* itself is said to be a development of the dental *s* by the rule which Whitney [16] states as follows: "The dental sibilant is changed to the lingual if immediately preceded by any vowel save *a* and *ā*, or by *k* or *r* — unless the *s* be final, [or] followed by *r*."

To be sure, there is a considerable number of Sanskrit words from the *Rigveda* down that show cerebrals which are not explained by this rule. These recalcitrants are disposed of by Whitney (*op. cit.*, § 46) as follows: ". . . in any other cases of their occurrence they are either products of abnormal corruption, or signs of the non-Indo-European character of the words in which they appear."

In support of the "non-Indo-European character" it is customary to call attention to the fact (or moot question) that Sanskrit contains Dravidian elements, that the Dravidas form the conquered substratum of the Indian population, and that Dravidian languages have cerebrals as an essential part of their phonetic system.

A little examination shows, however, that Dravidian contains but two cerebrals: an unaspirated stop, which is voiced or voiceless according to its position; and the nasal, which in all languages is prone to assume the position of the following consonant. Dravidian possesses no sibilant of any kind except in loan words.[17] Hence the mischief-maker of Sanskrit, the cerebral *ṣ*, could not have come from Dravidian. It would seem much more probable that in Old Sanskrit (as in Greek) the cerebral sibilant was the original Idg. sound retained under certain conditions, but assimilated to a dental *s* when initial in a word, when standing before the low vowels, and when following *p* or *t*.

Whether the Sanskrit *r* and *ṛ* were originally cerebral, as Panini states, is open to considerable doubt, for the pratiçakyas require a dental pronunciation (Whitney, *op. cit.*, § 52). Certainly these letters exercised no such cerebralizing effect as the cerebral sibilant did. Indeed, the combination of *r* + sibilant always appears as *rṣ*, but the combination sibilant + *r* is always *sr*. Of this apparently anomalous phonetic behavior of *r* Whitney remarks (*op. cit.*, § 181):

[16] Whitney, W. D., *A Sanskrit Grammar* (Leipzig, 1891), § 180.

[17] Caldwell, R., *Comparative Grammar of the Dravidian Languages* (London, 1913), pp. 131, 146.

"This dissimilating influence of a preceding *r* is peculiar and problematical."

If the fixed idea that the basic Sanskrit sibilant is a dental, which under certain circumstances is converted into a cerebral, were reversed — if grammarians held the theory that the original sibilant was the cerebral, which under certain circumstances became a dental — we should have here merely another case of the common Sanskrit law of progressive assimilation; in *rṣ* we have an assimilation of *r* to the following cerebral; in the case of *sr* the cerebral is assimilated to the dental. This would seem to offer a ready explanation of Whitney's "peculiar and problematical dissimilating influence."

From the point of view of linguistic mechanics also this alleged change of dental *s* to cerebral *ṣ* is difficult to explain. After the palatal *i* the natural assimilation would be that to palatal *š*, not to the cerebral *ṣ*; *iṣ* is a more difficult combination than *is*, and *iš* is easier than either. Moreover, under precisely the same circumstances (after *i, u, k, r*) we find in Avestan the palatal *š* and in Slavic the velar spirant *ch*. If there is anything about the production of *u*, dental *r*, or *k* that should bring about a palatalization or a cerebral pronunciation of a following sibilant I am at present unable to discover it. These sounds, however, are neutral and would exert no influence in changing an original cerebral to a dental.

Furthermore, if the sounds that supposedly caused cerebralization of a dental sibilant really exerted any such influence, it should be seen also in its effects on the dental stops. But neither Sanskrit and Avestan, nor Slavic nor Baltic shows any change whatsoever in such combinations, and Sanskrit grammarians interpret every cerebral stop in the language as a dental stop cerebralized.

In Slavic the Idg. sibilant appears as χ (*ach*-Laut) after *i, u, r, r,* and *k,* i.e. it corresponds to the extent of the cerebral in Sanskrit. As in the case of Sanskrit–Prakrit–Pali, this sound seems to have pleased the Slavs and has considerably outgrown its confines (as did the Oriental cerebral), but its original bounds are undisputed.[18]

What was the quality of this Slavic χ? The Cyrillic alphabet indicates it by the Greek letter chi, as does the Glagolithic, but the Greek chi has, of course, two values, that of the palatal *ich*-Laut and that of the velar *ach*-Laut. Before a back vowel it is velar, e.g.

[18] This matter is exhaustively treated by Holger Pedersen in *Indogermanische Forschungen*, V (1895) : 33 ff.

χαρτοφυλάκιον: before any of the numerous front vowels it is palatal, e.g. χαῖρε ὦ φίλε. It is quite possible that these values existed in St. Cyril's time, and it is possible, perhaps, that his Old Bulgarian had the palatal value of the metamorphosed Idg. *s*, although in the modern Slavic dialects it seems that everywhere the velar sound prevails.[19] That this Slavic velar spirant should have developed directly from an Idg. dental sibilant seems phonetically impossible, but the way from *ṣ* to *ç* and by posterior articulation to the corresponding χ may be paralleled, e.g. our inverted cerebral *r* of English becomes by posterior articulation the dialectic *w*, *robber* · *wobbah*.[20] Such a procedure, however, could hardly take place with the dental *r* of the Romance languages. A still closer parallel of the posited Slavic procedure is that of Old Spanish *š* (*dixe*) to the modern Spanish χ in Castilian *dije*.

The residue of the Idg. sibilant in Slavic was then in connection with low vowels and with consonants that favored a dental rather than a cerebral pronunciation. The exception is the original combination *si*, which became a palatal *š*, as it frequently does elsewhere.

In Slavic, as in Sanskrit, it seems to me that the sibilant must have been articulated at a point different from that of the dental stops, since a preceding *i*, *u*, *r*, *ŗ*, or *k* did not affect the stops, although they are particularly liable to change from palatalization.

In Armenian the Idg. sibilant fared badly, since it disappeared almost everywhere without leaving a trace in the modern language. However, the *s* that was retained was indicated by St. Mesrob (Mastoç) and his Greek coadjutor by the current Greek sigma of their time, in spite of the fact that they drew on the Syrian and even on the Coptic alphabet to supplement the Greek and invented new characters where the three systems of writing were unable to supply a symbol. The Armenian alphabet is also no rough approximation, but a painstaking attempt to represent every sound in the language. It contains separate symbols not only for *s*, *z*, *š*, and *ž*, but also for the affricates *ts*, *tsh*, *dz*, *tš*, *tšh*, and *dž*.

[19] Broch, Olaf, *Slavische Phonetik* (Heidelberg, 1911), § 22: "Der (dem *j*) entsprechende stimmlose Spirans, das *ç*, ist mir als selbständiges Lautelement, als 'Stellungslaut,' bei den Slaven nicht begegnet, erscheint jedoch oft als Gleitlaut nach der Explosion eines vorderpalatalen Verschlusslautes."

[20] Pedersen, *op. cit.*, p. 74: "Das aus Dental vor Dental entstandene *s* ist niemals zu *ch* geworden. . . . Das slavische *ch* ist m. Ansicht nach aus *š* entstanden; ich erinnere an die bekannte parallele aus dem Spanischen."

Corroborative evidence of the cerebral quality of the Idg. sibilant is offered by Avestan in that the sound has frequently become a palatal sibilant without discoverable palatalizing influences. In Albanian it is frequently represented by *ś*, never by *s*.[21]

Evidently Celtic can be of no assistance to us in determining the value of the Idg. sibilants because it shows but a single *s* and that is subject only to the change caused by the Celtic aspiration (*Lenierung*).

The situation in Hittite also seems to indicate a cerebral as the only sibilant. Sturtevant [22] states: "The Hittite system [of phonetic writing] must be traced to that of early Babylonia. . . . The Akkadian texts discovered at Boghazköi and Akkadian words and phrases in the Hittite texts themselves follow the early Babylonian system in general, although there are many simplifications and other differences in detail." In § 60 he continues: "Of the four Akkadian sibilants, S, Ṣ, Š, Z, Hittite employs the signs for the last two only, of which Š represents the sound that developed out of IE *s*. [From reference to § 142 it appears that IE, i.e. Indo-European, should be IH, i.e. Indo-Hittite, Pre-Indo-Germanic.] We may be sure that the Hittites would not have chosen Akkadian Š instead of S if the latter had resembled their sibilant more closely than the former, either Akkadian Š was closer to the Hittite sibilant or both Š and S were equally close. There is evidence that in classical Assyrian and indeed in Western Akkadian generally Š had become S, although the two were generally kept distinct in traditional orthography. There is then a probability that the Hittites learned cuneiform writing from speakers of Akkadian who pronounced both Š and S as [s]. The transliteration of Hittite names with Egyptian s instead of š . . . seems to settle the matter.

"Perhaps the strongest evidence in favor of pronouncing the Hittite sibilant as [ʃ] is the consistent writing of Hittite names in Akkadian documents with Š rather than with S; and yet even this may be only a result of the Hittite orthography itself. If the southern Akkadians learned the names Mursilis, Supilulyumas, and the rest through diplomatic correspondence, they would naturally retain

[21] Holger Pedersen attempts to prove that Albanian *h*, θ, and *ǵ*, are all developments of *s* (*Zeitschrift für vergleichende Sprachforschung*, 36 (1900) : 278 ff.).

[22] Sturtevant, E. H., *Comparative Grammar of the Hittite Language* (Phila., 1933), § 18.

whatever spellings appeared in the letters . . . . The two sibilants are generally kept distinct in Akkadian texts from Boghazköi, but that may be due entirely to tradition."

In connection with these statements it is pertinent to quote Delitsch:[23] "Im Babylonischen . . . hat *š* so gut wie niemals aufgehört, seine älteste, ursprüngliche Aussprache zu bewahren. . . .

"Dagegen hat im Assyrischen das *š* seine Aussprache als *sch* mehr und mehr aufgegeben und sich allmählich ganz mit *š* vereinerleit."

We apparently have the same situation here as in Greek, an Indo-Germanic-Hittite cerebral *s*, which the natives attempted to express with Semitic phonetic symbols. The cerebral was not precisely any one of the Semitic phonemes, but it sounded to its users most like shin; hence the Greek sigma from Phoenician shin, and the Hittite *š*-signs from the Babylonian syllabary. The Semites, attempting to represent the foreign sound, had the same difficulty; it was neither sin nor shin. The Akkadians settled the matter by choosing *š*, just as the Arabs centuries later employed shin to transliterate Hindustani cerebral *ṣ*; but the Egyptians chose *s*, as the Aramaeans later used samech to transliterate Greek sigma.

The fact that the Hittite system of writing "must be traced to that of early Babylonia," where the distinction of *š* and *s* was always maintained, shows that the Hittites made a deliberate choice between sounds, not between two indifferent symbols for the same sound.

Let us now consider the probability that Idg. may have had several sibilants. If such had been the case we should expect to find by comparison of the Idg. languages that the sibilant behaved differently under the same circumstances; for example, that an original Idg. **sa* would appear in Greek in a form different from a **ṣa* or a **ša*, and that an original **-kš* would have developed in Slavic otherwise than a **-ks*. However, nothing of the sort occurs; all sibilants develop alike in a given language under the same circumstances, so far as it is possible to control them.

Also if there had been a palatal *š* in Idg. it should have fallen together in the satem languages with the resultants from the palatal stops. This is not the case, for the sibilant developed from the palatals never falls together with the descendants of Idg. *s* in Sanskrit, Avestan, Albanian, Baltic, or Armenian. In Slavic, to be sure, both are now usually *s*, but that there was originally a distinction

[23] Delitsch, F., *Assyrische Grammatik* (Berlin, 1906), § 63.

is shown by the fact that the resultant from the palatal never shows the change to χ.

But this involves the duty of investigating the steps by which a single original sibilant might have developed to the various phonemes that we have observed.

The change of *s* to *h*, with eventual reduction of *s* to zero, is a very common one; Sanskrit, Avestan, Armenian, Greek, Albanian, Welsh, and (by aspiration) Irish show it as a regular occurrence. It is characteristic also of the Andalusian dialect, as in *do soldado* or *doh soldadoh* (Castilian *dos soldados*); and it accounts for the form of French words such as *étroit*, *état*, *été*.

But not only *s* becomes the glottal spirant by a weakening of the articulation; *f* also shows the same development in Spanish (cf. *facere–hacer*, *faba–haba*), and in Armenian and in Old Irish the Idg. *p* has gone the same way by the intermediate step of *f*. Also the χ of primitive Germanic has usually become *h* or has disappeared when it was not in a consonantal group (**dek̂m̥*, δέκα, *taihun*, *ten*). Note also the Sanskrit visarga for both final *r* and final *s*, and the fact that the original feminine 3rd s. verbal ending *–t* (Arabic *qatalat*) has become in Hebrew ה through the intermediate step of ת.[24] It seems that any surd spirant whatsoever becomes the glottal spirant if for physical reasons or from the force of fashion its articulation is relaxed or prevented. Thus a smoker with his pipe in his mouth cannot pronounce the interdental and says "*Hank you*" for "*Thank you*," and a painful crack in the lips will tend to make the speaker say "*hind*" for "*find*." Whether or not there is a simultaneous approximation of the vocal cords to produce a hiss with every surd fricative, or whether the hiss is an involuntary compensation for a constriction elsewhere that is formed only laxly or not at all, is a problem for experimental phonetics to settle. I am inclined to believe that it is the latter, that it is the result of the speaker's bad conscience for the omission of an articulation which he knows should be made; it is in the nature of a back-seat driver's tramping on a brake that does not exist. Fashion dictates that the spirant be not vigorously articulated; the consciousness that something is omitted causes a compensatory twitch of the highly sensitive nerve that controls the vocal cords, and a glottal spirant is the result.

If this is true, the frequent change of *s* to *h* can prove nothing as

[24] O'Leary, *op. cit.*, pp. 54–55.

to the quality of the original sound, and there is no gradual transition to the ultimate sound from generation to generation of speakers.

The disappearance of this or of any other *h* is a familiar phenomenon of language; the Greeks named it "psilosis" and noted its prevalence among Ionians long before the beginning of our era. It may be due ultimately to the failure to hear the sound, just as our young people are frequently unable to decide on the correct pronunciation of *humor, herbs,* etc.

The phenomenon of ancient and modern dental *s* from cerebral *ṣ* can be explained in a number of ways: (1) the desire to distinguish the phoneme from the palatal *š*; (2) the development of a dental *s* from dental stops and ultimate coalescence; (3) the substratum influence; (4) assimilation.

It remains for us to consider the changes involved in the Albanian *θ* and *ǵ* and the Slavic *χ*. Of these the change to the interdental is paralleled in our own times by the Castilian development of *nación* from *nationem*. It involves an intermediate stage of dental *s*, but this *s* may again be from various origins, particularly from the displacement of another sibilant articulation or from the resolution of a dental affricate.

The Albanian *ǵ* is said to be a palatalized *g* + a palatal voiced sibilant.[25] It is not unusual that a spirant becomes an affricate by the accretion of a homorganous stop; cf. the Berliner *tcha, dja* for *ja*; the Spanish-American habit of saying *ǧa, ǧo* for *ya* and *yo*; and the Gothic development of intervocalic *jj* and *ww* to *ddj* and *ggw* (Old Norse even shows a change of the *ddj* to *ggj*, e.g. *eggja* [gen. pl.]). The Albanian development is no doubt similar, and the starting point may well have been the cerebral voiced sibilant, which shifted to a pure palatal, after which the initial stop developed; cf. *ǵarper* ("snake"), Greek ἕρπω; but *šterpi* ("creeping"), from the *Tiefstufe* of the root **serp*.

The Slavic development of *s* to the *ach*-Laut would seem to lead over the palatal fricative (*ich*-Laut). Indeed we can easily imagine the succession of the stages *ṣ ç–χ*, and it is possible to cite examples for the confusion of each of these successive stages with the preceding one. At any rate, whatever the various steps in the Albanian and Slavic developments may have been, the starting point *ṣ* seems more plausible than *s* in both languages.

[25] Pekmezi, Georg, *Grammatik der albanesischen Sprache* (Vienna, 1908), § 8.

I think it probable, then, that:

(1) Idg. had only one voiceless spirant, for no language shows a divergent treatment of the primitive sibilant under identical conditions.

(2) Idg. *s* was not palatal, for it did not fall together with the *š* developing from the palatal stop. Also Semitic transcriptions from Idg. languages represent the sound by means of samech and sin, not by shin.

(3) Idg. *s* was not dental, for it sounded like the Semitic *š* to the ancient Greeks and Romans and to the Hindoos, while Herodotus identified it with the Persian *š* and the Hungarians with their *š*. In Germanic and Albanian it was kept apart from the sibilant that developed from a dental; and that it was a near palatal is proved by the Old Norse *r*-umlaut.

(4) The cerebral *ṣ* in the Brahmi and the Devanagari alphabets is a persistence of an Idg. value, for it is the sound that best fits Idg. developments.

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A QUARTER CENTURY (1912–36) OF METEOROLOGICAL DATA, DOUGLAS LAKE, MICHIGAN *

FRANK C. GATES

THE present paper is a summary of the first twenty-five years' meteorological data obtained at the Biological Station of the University of Michigan at Douglas Lake, Cheboygan County, Michigan. It continues previous articles in the volumes of the Michigan Academy. The first one, which covers the period from 1912 through 1918, appeared in the *Annual Reports*, 21 : 373–378. Two later ones, published in the *Papers*, 2 : 475–489 and 14 : 603–612, bring the records through 1923 and 1929, respectively. Since 1929 records have been taken on the new station site about one-half mile to the west. These records were obtained from standard weather bureau instruments. The maximum and minimum thermometers were exposed in a standard shelter with the solar thermometer and the 8-inch rain gauge near by. These instruments were read twice daily.

In this article temperature is expressed in degrees Fahrenheit, precipitation in inches, evaporation and solar intensity between 1915 and 1922 in c. c. per day, and dragoyle [1] readings in beats per minute. Averages are calculated from the grand totals. They are usually based on 25 years' records of the periods in which the Biological Station was in session and of shorter periods before and after the sessions, as shown in the tables. These records indicate that the summers are mild, with few periods of extremely high temperature and, usually, with fair to moderately warm days and cool nights; there is a high percentage of sunshine, and normally but a

* Contribution No. 365 from the Department of Botany, Kansas State College, Manhattan, Kansas, and a contribution from the Biological Station of the University of Michigan.

[1] Gates, Frank C., and Black, Robert L., "The Dragoyle as an Ecological Instrument," *Ecology*, 12 : 448–451. 1931.

modest amount of rain during the summer—sometimes even to the point of severe drouths.

METEOROLOGICAL SUMMARIES, 1912–36

(Table I)

Table I includes Tables III, II, and I, respectively, of the three publications already cited, but brings the data through 1936. The summaries of evaporation from standardized Livingston atmometers and solar intensities from standardized blackened Livingston atmometers are included for the period between 1915 and 1922. Solar intensity is expressed as c.c. of water evaporated from a black spherical atmometer in excess of that evaporated from a white atmometer. From 1926 on, solar temperatures were obtained by a standard black bulb *in vacuo* exposed in the usual manner. From 1931 on, dragoyle readings were taken morning, noon, and night.[2]

METEOROLOGICAL AVERAGES, 1912–36

(Table II)

In Table II various meteorological features are shown for each fifth of a month. In June the temperature and the precipitation are for from 7 to 21 years of record, as shown in the table; those for July and August, except the last periods, are for 25 years. The data for solar maximum temperatures are based on 11 years of record; and the barometer data and dragoyle readings, on 6 years.

METEOROLOGICAL DATA, 1930–36

(Tables III–V)

The daily maximum, minimum, and solar maximum temperatures and precipitation bring the printed record to date. All these records have been made with standard weather bureau instruments properly exposed.

METEOROLOGICAL EXTREMES

During the past 25 years the temperature has reached or exceeded 100° F. fifteen different times: once in 1911, three times in 1916,

[2] For the construction and operation of the dragoyle see footnote 1. The figures give the number of beats of this instrument per minute, each beat being equivalent to the evaporation of 0.0006081 c.c. of water.

twice in 1917 (104° on July 31, 1917, the highest on record), once in 1921, once in 1927, once in 1931, and six times on consecutive days in 1936. The summer temperature has fallen to 35° or below eight times: once in 1918, twice in 1921 (28° on June 4, 1921, the lowest on record), twice in 1922, twice in 1925, and once in 1928. There have been eight periods of no measurable precipitation for fifteen or more days: one each in 1917, 1919, 1928, 1929, 1930, 1933, and two in 1936 (19 days each, the longest on record). Considering rains of agricultural importance as 0.25 inch in a day, there have been nineteen periods of drouth of twenty or more days: one each in 1913, 1915, 1916, 1918, 1919, 1925, 1927, 1929, 1930, 1931, 1932, 1933, 1934, 1935, 1936 (44 days, the longest on record), and two each in 1923 and 1926.

Hail storms are unusual. Only three have occurred since the establishment of the Biological Station, and each covered but a slight area.

A single tornado went through a small section of the district in the earlier years of the Station and twisted down large hemlocks on both sides of its path. Heavy windstorms, however, are more frequent. Two or three are expected every summer.

Displays of aurora borealis also take place several times each summer. In 1918 they were particularly spectacular.

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TABLE I

WEATHER SUMMARIES, DOUGLAS LAKE, MICHIGAN

MONTH AND YEAR	TEMPERATURE					PRECIPITATION		EVAPORATION	SOLAR INTENSITY
	Abs. max.	Av. max.	Abs. min.	Av. min.	Mean	Ppt.	Days ppt.		
July, 1912	95	77.6	45	57.5	67.7	1.06	9	....	....
Aug., 1912	84	68.7	41	53.8	61.2	6.79	11	....	....
July, 1913	93	78.5	42	56.7	67.8	3.07	10	....	....
Aug., 1913	97	82.0	46	60.1	71.0	0.51	3	....	....
July, 1914	94	81.8	46	58.2	70.0	1.84	7	....	....
Aug., 1914	98	80.0	46	56.5	68.0	1.71	8	....	....
July, 1915	92	77.6	44	54.6	66.1	1.69	13	14.2	....
Aug., 1915	84	73.1	48	55.6	64.1	3.76	7	11.4	....
July, 1916	102	87.3	44	61.2	74.2	1.07	5	45.0	....
Aug., 1916	99	82.3	42	59.4	70.7	1.66	7	27.0	....
July, 1917	104	81.3	50	60.3	70.9	1.33	10	36.3	11.0
Aug., 1917	86	76.2	43	56.6	66.2	2.14	9	24.3	6.1
July, 1918	98	79.2	39	55.2	67.2	1.39	7	29.9	....
Aug., 1918	90	79.9	42	55.9	67.6	2.52	8	25.4	....
July, 1919	96	81.8	38.5	55.2	66.9	1.23	6	31.1	16.1
Aug., 1919	90	76.4	46	56.3	66.4	2.03	5	22.5	11.9
June, 1920	96	78.3	43	56.2	67.3	2.34	10	....	....
July, 1920	87	73.1	39.5	52.4	62.7	2.77	11	32.6	8.6
Aug., 1920	88	76.4	40	53.0	64.7	3.54	6	28.8	6.2
June, 1921	91	82.6	28	54.6	68.6	1.11	5	....	....
July, 1921	100	87.6	52	62.8	75.2	2.41	9	34.1	17.9
Aug., 1921	87	72.4	43	54.2	63.3	4.13	11	23.4	11.7
June, 1922	87	71.8	30	50.5	60.9	2.92+	6	....	....
July, 1922	87	74.4	42	54.1	64.3	6.05	12	21.9	9.3
Aug., 1922	91	76.6	45	55.9	66.1	2.27+	4	19.0	12.4
June, 1923	95	79.2	37	52.5	65.9	1.85	5	....	....
July, 1923	94	81.6	45	53.0	67.3	1.62	10	....	....
Aug., 1923	89	74.7	37	49.4	61.6	3.21	8	....	....
June, 1924	87	75.1	43	49.9	62.5	1.69+	5+	....	....
July, 1924	91	77.0	41	52.7	64.9	3.87	11	....	....
Aug., 1924	89	73.6	42	52.9	63.2	4.47	9	....	....
June, 1925	80	71.5	34	47.8	59.6	3.40+	10+	....	....
July, 1925	91	77.2	40	52.5	64.8	2.99	9	....	....
Aug., 1925	95	83.9	49	54.9	69.4	0.13+	3+	....	....

TABLE I (*Concluded*)

Month and Year	Temperature							Precipitation		Dragoyle Reading		
	Abs. max.	Av. max.	Abs. min.	Av. min.	Mean	Solar max.	Av. solar max.	Ppt.	Days ppt.	6:30	Noon	6:00
June, 1926	82	72.4	36	48.3	60.3	—	—	0.84+	5+	..	..	..
July, 1926	91	80.7	40	51.6	66.1	154	140	2.40	9	..	..	..
Aug., 1926	90	76.8	44	55.7	66.2	156	135	2.13	12	..	..	..
June, 1927	98	—	37	—	—	—	—	—	—	..	..	..
July, 1927	102	79.0	38	53.2	66.1	159	135	2.71	10	..	..	..
Aug., 1927	86	74.6	36	46.4	60.5	145	137	0.15+	2+	..	..	..
June, 1928	82	73.5	35	51.1	62.3	148	127	3.64+	8+	..	..	..
July, 1928	97	79.5	43	56.1	67.8	151	137	3.25	12	..	..	..
Aug., 1928	91	81.8	46	55.9	68.8	156	140	2.24	3	..	..	..
June, 1929	93	77.8	42	51.5	64.6	152	—	2.66+	7+	..	..	..
July, 1929	95	81.4	40	53.5	67.4	156	—	2.47	8	..	..	..
Aug., 1929	87	74.8	39	50.7	62.7	151	140	2.52	8	..	..	..
June, 1930	—	—	—	—	—	—	—	—	—	..	..	..
July, 1930	91	78.8	46	56.4	67.6	159	147	2.38	8	..	..	..
Aug., 1930	92	80.8	48	58.2	69.5	157	146	0.43	3	..	..	..
June, 1931	98	—	—	—	—	159	—	2.25+	2+	..	..	..
July, 1931	100	82.7	52	60.6	71.6	159	144	2.68	9	16	61	60
Aug., 1931	96	80.5	51	58.5	69.3	155	140	0.43+	4+	12	69	60
June, 1932	80	73.9	44	52.7	63.3	150	—	0.69+	3+	9	57	50
July, 1932	89	77.6	45	57.4	67.5	155	144	3.15	10	15	64	60
Aug., 1932	92	79.3	46	58.1	68.7	154	143	2.58	9	11	63	60
June, 1933	95	87.4	58	63.0	70.2	158	—	0.36+	2+	15	66	57
July, 1933	96	82.9	47	59.1	71.0	155	146	3.34	5	17	63	65
Aug., 1933	88	77.1	45	55.2	66.1	152	139	1.90	8	8	63	61
June, 1934	90	76.9	45	54.5	65.7	147	—	1.54	7+	6	44	55
July, 1934	89	79.9	48	57.6	68.8	152	141	1.90	8	13	64	56
Aug., 1934	89	73.8	39	51.9	62.9	147	134	2.88	10	5	50	44
June, 1935	82	74.9	50	53.0	64.0	150	—	1.52+	6+	..	..	..
July, 1935	95	83.6	50	62.0	72.8	161	144	1.56	9	17	59	58
Aug., 1935	88	76.2	45	58.9	67.5	150	136	4.24	13	8	49	48
June, 1936	82	74.3	46	51.3	62.8	155	—	0.12+	1+	..	..	..
July, 1936	103	84.5	44	59.4	72.0	158	144	0.81	4	17	73	73
Aug., 1936	90	76.2	49	56.9	66.5	152	128	4.19	11	15	65	62

TABLE II

Meteorological Averages, 1912-36, Douglas Lake, Michigan

Periods	Year of record	Absolute maximum	Absolute minimum	Average maximum	Average minimum	Mean	Solar maximum absolute	Solar maximum average	Precipitation	Days precipitation	Maximum precipitation in one day	Barometer	Dragoyle reading 6:30	Dragoyle reading Noon	Dragoyle reading 6:00
June 1–6	..	84	28	....	....	....	...	...	....	...	....	....	..	..	..
7–12	7	96	38	76.4	52.9	64.7	...	...	0.60	1.6	1.20*	....	..	..	..
13 18	10	93	34	76.1	50.4	63.3	152	131	0.77	1.3	2.24	....	..	..	..
19 24	17	95	36	76.6	52.2	64.4	148	138	0.38	1.5	1.48	29.32	9	63	62
25-30	21	98	30	76.9	53.3	65.1	159	139	0.55	1.7	1.64	29.27	10	57	52
Average or extremes	..	98	28	76.5	52.2	64.3	159	138	2.29 +	6.1 +	2.24	....	..	..	..
July 1 6	25	102	38	79.3	53.0	66.1	159	141	0.43	1.5	1.00	29.31	15	63	56
7-12	25	102	38.5	79.9	56.4	68.2	159	141	0.53	2.0	1.73	29.34	16	66	66
13-18	25	103	42	80.3	56.8	68.6	156	144	0.47	1.8	1.50	29.32	18	62	68
19 24	25	100	40	80.9	57.4	69.1	161	143	0.53	1.8	1.36	29.27	15	59	59
25 31	25	104	40	80.8	57.6	69.2	157	141	0.42	1.8	0.85	29.32	15	67	63
Average or extremes	..	104	38	80.2	56.3	68.2	161	142	2.36	8.8	1.73	29.31	16	63	62
Aug. 1-6	25	99	36	78.0	56.0	67.0	156	137	0.53	1.5	1.97	29.35	13	62	59
7-12	25	98	38	77.8	56.0	66.9	157	141	0.68	2.2	2.20	29.34	8	56	52
13 18	25	97	40	77.6	55.2	66.4	154	140	0.52	1.5	1.28	29.38	11	64	57
19-24	23	97	39	75.7	54.4	65.0	152	138	0.52	1.4	1.45	29.43	7	55	61
25-31	16	91	37	73.8	53.6	63.7	156	132	0.47	1.3	1.92*	29.34	..	..	..
Averages or extremes	..	99	36	76.6	55.0	65.8	157	138	2.72	7.9	2.20	29.37	10	59	57

* Two days.

TABLE III

MAXIMUM AND MINIMUM TEMPERATURES, DOUGLAS LAKE, MICHIGAN

(Degrees Fahrenheit)

DATE	1930		1931		1932		1933		1934		1935		1936	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
JUNE 18	..	..	..	..	..	..	..	..	75	56	..	..	..	..
19	..	..	..	..	..	..	..	..	74	53	..	..	..	..
20	..	..	..	..	..	..	..	..	85	50	..	..	..	..
21	..	..	71	52	..	..	..	..	69	54	63	..	..	..
22	..	..	—	50	..	..	..	..	71	45	61	50	..	..
23	..	..	—	—	..	..	82	..	90	52	72	52	..	..
24	..	..	81	48	69	44	84	—	80	59	78	50	81	..
25	..	..	83	65	67	55	84	58	71	55	79	50	82	57
26	—	—	80	59	80	48	84	58	58	54	80	60	68	52
27	69	56	85	59	73	61	94	60	75	52	78	51	79	51
28	73	48	84	66	78	50	90	68	87	61	75	55	68	49
29	77	53	91	61	75	57	95	66	80	59	82	52	71	46
30	72	60	98	69	75	54	86	68	85	58	81	57	71	53
JULY 1	66	52	100	72	67	52	79	65	78	59	73	62	76	44
2	71	47	79	71	64	52	75	59	86	57	78	57	69	55
3	69	48	82	60	72	45	80	52	73	57	89	60	76	50
4	77	46	78	59	70	52	85	47	81	48	86	65	81	51
5	82	58	78	60	74	50	84	53	78	63	92	64	83	54
6	79	54	82	55	79	56	89	67	75	56	74	61	89	53
7	78	54	79	57	75	57	81	63	71	50	63	52	98	56
8	83	58	81	53	78	56	78	61	78	48	78	59	101	70
9	82	60	74	55	84	55	82	56	84	51	85	61	100	73
10	83	58	75	52	79	63	85	55	73	63	88	63	102	75
11	75	59	78	53	74	59	84	55	84	57	89	68	101	77
12	69	54	85	52	88	53	90	55	85	64	81	67	102	73
13	65	52	80	62	84	70	90	62	83	63	78	61	103	74
14	69	47	86	56	79	58	80	66	89	59	74	56	84	74
15	75	48	90	65	72	56	79	55	77	62	74	57	86	62
16	84	53	83	65	88	57	73	53	74	50	79	50	89	59
17	87	58	95	70	75	60	75	50	78	52	88	59	85	64
18	86	66	85	65	84	54	76	50	89	52	89	61	81	63
19	82	61	96	64	87	63	80	56	88	67	89	68	78	61
20	83	54	82	65	81	65	84	64	87	68	95	68	78	55
21	77	60	76	62	88	68	85	65	79	60	91	69	81	53
22	74	58	77	54	78	62	86	66	79	65	87	67	79	57
23	82	52	72	56	70	55	86	66	87	55	87	64	76	60
24	83	63	78	55	79	49	76	55	87	67	90	64	74	58
25	90	59	84	56	89	61	82	54	85	65	85	68	76	52
26	79	63	90	60	75	68	78	57	79	60	90	61	79	50
27	91	64	92	68	74	56	80	55	83	54	92	64	83	57
28	83	68	96	72	69	56	88	63	72	53	78	65	78	58
29	75	55	79	64	70	55	93	66	74	49	84	60	69	51
30	75	57	81	59	79	55	92	72	69	58	79	59	78	52
31	79	53	69	60	81	60	96	70	72	54	86	63	85	52

TABLE III (*Concluded*)

Date		1930		1931		1932		1933		1934		1935		1936	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Aug.	1	83	54	72	57	85	55	78	66	80	50	78	66	88	59
	2	92	67	85	58	79	56	68	58	76	58	79	55	84	62
	3	91	72	77	60	81	62	73	55	73	58	79	65	80	65
	4	85	68	87	58	88	61	77	54	77	51	76	60	74	56
	5	89	60	96	62	77	62	82	55	73	52	80	57	78	50
	6	86	60	82	67	78	54	86	54	83	48	67	60	78	56
	7	89	65	70	60	75	55	78	62	86	62	77	62	86	53
	8	88	64	72	61	71	53	74	58	89	63	83	60	90	60
	9	79	59	75	62	79	54	79	50	89	64	78	59	89	61
	10	68	58	75	57	76	58	85	56	78	60	83	60	75	59
	11	65	52	72	54	71	56	77	62	74	56	83	64	82	52
	12	75	48	78	55	75	55	76	59	83	59	78	69	79	55
	13	75	50	80	58	82	56	68	54	73	62	77	62	82	61
	14	76	58	86	54	83	55	73	50	71	49	76	57	76	63
	15	74	52	77	64	85	55	83	50	72	52	88	58	78	60
	16	73	55	89	58	88	62	78	52	81	56	87	63	78	60
	17	73	54	91	59	81	64	75	62	87	56	84	67	74	53
	18	73	55	88	60	66	55	63	55	88	64	84	69	85	51
	19	78	57	77	61	67	50	76	45	75	60	86	67	75	63
	20	76	57	75	58	79	46	82	50	62	46	77	70	71	51
	21	78	58	81	52	83	53	82	50	73	44	67	55	73	56
	22	82	58	86	51	83	59	82	50	65	49	74	50	88	60
	23	83	62	..	..	82	58	80	55	76	43	72	57	77	66
	24	82	59	..	..	89	62	86	61	61	46	77	47	72	59
	25	83	58	..	..	82	69	88	61	68	39	72	57	63	53
	26	85	57	..	..	79	64	75	60	63	46	77	56	61	54
	27	91	58	..	..	70	60	72	51	56	46	67	55	69	56
	28	81	61	..	..	75	55	64	55	60	42	59	49	64	55
	29	75	56	..	..	68	59	73	55	62	41	61	46	59	53
	30	86	50	..	..	92	65	79	50	71	40	60	45	69	53
	31	89	61	..	..	89	72	..	..	64	48	..	..	65	49

TABLE IV

PRECIPITATION IN INCHES, DOUGLAS LAKE, MICHIGAN

DATE	1930	1931	1932	1933	1934	1935	1936
JUNE 17	...	...	...	...	...		—
18	...	...	...	...	0.21	1.34	—
19	...	...	...	...	—		—
20	...	...	...	...	tr		—
21	...	—	...	...	0.27	—	—
22	...	0.61	...	...	0.13	0.04	—
23	...	—	...	—	—	—	—
24	...	—	—	0.34	—	—	—
25	...	—	0.09	—	0.04	tr	tr
26	0.01	tr	tr	—	0.59	tr	—
27	—	—	—	—	—	0.14	0.12
28	—	1.64	—	tr	—	—	—
29	0.53	tr	0.26	0.02	0.01	—	tr
30	0.88	—	0.34	tr	0.29	—	tr
JULY 1	—	—	0.01	—	—	0.08	—
2	—	tr	—	—	—	0.08	0.01
3	—	—	—		—	—	—
4	0.13	—	—	—	tr	—	—
5	0.59	0.78	tr		—	—	—
6	—	—	0.13	—	0.63	0.09	—
7	—	—	0.07	—	—	0.01	—
8	tr*	—	—	—	—	—	—
9	—	—	—	—	—	—	—
10	0.15	—	0.13	—	0.21	—	—
11	—	tr	—	—	—	0.02	—
12	1.02	0.03	—	—	—	—	—
13	0.01	0.06	—	—	0.18	—	—
14	—	tr	0.27	tr	—	0.03	—
15	—	—	0.93	—	—	—	—
16	—	1.50	—	—	—	—	—
17	tr	tr	—	0.03			—
18	—	—	—	—	tr	—	—
19	—	0.21	—	1.19	0.09	—	—
20	0.15	—	0.68	0.75	tr	—	—
21	0.02	0.01	0.52	—	0.09	—	—
22	—	0.05	—	0.01	—	—	0.58
23	—	tr	—	1.36	—	—	0.13
24	—	—	—	—	—	0.25	—
25	—	—	tr	—	—	—	—
26	0.31	—	0.10	—	—	—	tr
27	—	0.03	—	tr	0.13	0.21	—
28	—	—	0.31	—	—	—	0.09
29	—	—	—	—	0.49	—	tr
30	—	—	—	—	0.08	0.79	—
31	—	0.01	—	—	—	—	—

* The notation "tr" means a trace, or less than 0.01 inch of precipitation.

TABLE IV (*Concluded*)

Date	1930	1931	1932	1933	1934	1935	1936
Aug. 1	—	0.05	—	0.44	0.05	—	—
2	0.32	0.29	0.53	0.22	0.53	—	—
3	tr	—	—	—	—	0.06	tr
4	—	—	—	—	—	0.51	—
5	—	—	tr	-	—	—	—
6	—	—	0.05	—	—	1.18	—
7	—	0.05	0.04	0.03	—	0.01	—
8	—	0.04	0.04	—	0.58	—	—
9	—	tr	—	—	—	0.52	0.28
10	—	tr	0.12	—	—	—	—
11	—	—	—	0.01	—	0.01	—
12	—	—	—	0.06	—	tr	tr
13	tr	—	—	tr	—	—	—
14	—	—	—	—	—	—	0.72
15	0.02	tr	—	—	0.33	—	—
16	—	—	—	0.03	-	-	-
17	—	—	0.15	0.99	—	0.22	—
18	—	—	0.03	0.12	0.48	0.15	0.02
19	—	—	—	—	0.24	tr	—
20	—	—	—	—	—	1.12	0.04
21	—	—	—	—	—	0.13	0.31
22	—	—	—	—	0.20	—	0.52
23	—	...	—	—	0.30	—	0.10
24	—	...	—	—	0.12	—	0.07
25	—	...	—	—	tr	tr	—
26	—	...	0.70	—	—	tr	0.63
27	—	...	tr	—	tr	tr	—
28	tr	...	—	—	—	0.29	1.40
29	tr	...	0.92	—	—	0.02	0.10
30	—	...	tr	—	—	0.02	—
31	0.09	...	—	...	0.05	...	—

TABLE V

SOLAR MAXIMUM TEMPERATURES, DOUGLAS LAKE, MICHIGAN
(Degrees Fahrenheit)

DATE	1930	1931	1932	1933	1934	1935	1936
JUNE 18	...	...	...	...	141	...	...
19	...	...	...	...	138	...	...
20	...	...	...	...	143	...	...
21	...	141	...	...	132	...	...
22	...	—	...	...	137	119	...
23	...	—	...	148	147	144	...
24	...	143	146	146	144	145	147
25	...	147	127	148	137	143	155
26	—	150	147	146	58	148	134
27	140	148	147	153	143	135	132
28	141	147	150	152	147	140	132
29	130	150	147	158	146	150	128
30	137	159	136	150	144	144	135
JULY 1	140	159	135	154	144	125	142
2	144	124	134	146	147	135	138
3	139	110	142	144	137	143	140
4	143	142	139	148	147	154	145
5	151	127	141	155	143	156	144
6	147	147	145	149	134	139	149
7	147	149	154	110	136	102	151
8	157	140	140	148	141	140	156
9	151	148	153	143	150	149	155
10	159	148	148	152	73	146	155
11	146	154	139	151	152	148	158
12	123	150	150	148	149	141	155
13	118	147	140	154	145	145	155
14	137	150	139	135	149	144	131
15	141	149	134	142	134	144	148
16	155	130	150	147	131	141	145
17	141	156	149	146	142	150	142
18	151	149	146	141	154	143	139
19	148	154	151	153	149	154	143
20	157	147	143	148	149	151	146
21	149	150	151	146	141	161	142
22	157	154	144	150	139	149	140
23	153	146	154	148	143	146	133
24	149	142	141	140	144	151	136
25	157	150	155	146	145	142	140
26	137	152	140	144	139	150	139
27	152	150	146	140	144	152	146
28	152	155	145	144	137	143	142
29	150	145	137	149	135	144	138
30	154	146	141	153	142	121	139
31	151	97	147	154	149	143	145

TABLE V (*Concluded*)

Date	1930	1931	1932	1933	1934	1935	1936
Aug. 1	151	130	154	140	141	139	144
2	152	141	139	68	139	149	130
3	154	145	141	142	137	136	107
4	149	148	149	147	141	142	133
5	156	155	149	149	138	149	152
6	148	144	144	152	143	67	134
7	157	104	145	138	147	139	141
8	150	104	147	139	147	145	145
9	145	145	150	143	147	121	141
10	143	147	144	150	141	143	141
11	135	139	138	139	137	139	140
12	150	140	141	142	144	146	117
13	140	143	151	138	132	143	135
14	143	154	154	139	134	150	131
15	140	117	152	145	129	146	135
16	139	150	146	134	140	145	133
17	139	150	148	142	145	139	135
18	140	142	135	135	141	143	135
19	141	141	138	138	133	148	137
20	140	138	143	143	132	102	133
21	145	146	147	143	135	134	135
22	143	152	143	142	129	141	144
23	143	...	128	141	142	137	134
24	143	...	146	149	128	138	135
25	148	...	146	145	128	138	116
26	143	...	145	140	130	142	84
27	151	...	135	136	98	137	126
28	151	...	145	136	137	125	67
29	142	...	92	143	129	132	75
30	152	...	152	143	131	120	132
31	150	...	149	...	87	...	121

OESTROGENIC ASSAY OF CERTAIN SYNTHETIC COMPOUNDS*

BENZANTHRACENE AND DIBENZANTHRACENE DERIVATIVES

JAMES T. BRADBURY

THE synthesis of a series of phenanthrene derivatives is the project of Dr. W. E. Bachmann of the Department of Organic Chemistry, University of Michigan. It has been our privilege to attempt to assay a number of these pure crystalline compounds for their oestrogenic activity. Some preliminary assay results on several 1.2-benzanthracene and 1.2.5.6-dibenzanthracene derivatives are presented in this paper.

METHODS

The assay technique is comparable to that employed by Allen and Doisy (1923). The material to be assayed is put into solution and injected into rats or mice which have been spayed for at least two weeks previous to the assay. Aqueous solutions are given in four divided doses over a forty-eight-hour period. Oil solutions are given in one injection on each of two successive days.

Sesame oil has been in general use as a solvent, but it is not readily absorbed. We have observed oil cysts present as long as six months after injection, and from the results of the development of neoplastic changes in association with these oil cysts it appears that some of the crystalline solute still remains in the oil. Peanut oil is more readily absorbed, so that it has been used as the solvent in the more recent experiments. Pincus and Werthessen (1936) reported that when substances are injected intraperitoneally it is possible to get oestrogenic activity with smaller doses than will give

* This study was made possible by a grant to Dr. Norman F. Miller, University of Michigan, from the Faculty Research Fund. The author is research assistant to Dr. Miller.

this effect subcutaneously. Their method has been used in part of the assays in this study and has been checked against subcutaneous injections of the same substances. In using the two methods we have not found as great a difference in activity as would be expected from their results.

The changes in the vaginal mucosa are observed by microscopic examination of material obtained from the vagina. A pipette or a wire loop is introduced into the vaginal canal once daily, and the material thus obtained is spread on a glass slide and allowed to dry. These spreads or smears are suitable for microscopic study without further fixation or staining. An active substance usually produces the typical cornification changes within 72–96 hours after the first injection.

ASSAYS

(Fig. 1)

Cook and his coworkers (1934) made the surprising discovery that some of the synthetic phenanthrene derivatives were oestrogenic. One of the compounds that they found most active was the dipropyl-dibenzanthracene-diol (9,10-di-n-propyl-9,10-dihydroxy-9,10-dihydro-1,2,5,6-dibenzanthracene; Formula A). They reported this substance to be oestrogenic in dosages as low as 0.025 mg. We have not approached this dosage, but the compound is very active. A vaginal cornification that persisted for 22–28 days was produced by 0.5 mg. This long period of response indicates the slow rate of absorption of this relatively insoluble substance when in sesame oil. The rate of absorption of the material may be affected greatly by the solvent. A dose of 0.4 mg. dissolved in propylene glycol produced vaginal cornification that persisted for 7–11 days, whereas 0.2 mg. in sesame oil was effective for 25–30 days. The propylene glycol is absorbed much more quickly than the sesame oil, and the crystalline solute is absorbed with it. This is further borne out in our experiments, in which we found that this substance in sesame oil gives rise to the formation of spindle cell sarcomata at the injection site. We have not succeeded in producing sarcomata with a propylene glycol solution unless it was a supersaturated solution which allowed the deposition of the crystalline material in the tissues. (Bradbury, 1936, and unpublished data.)

A second compound (9,10-di-n-propyl-9,10-dihydroxy-9,10-dihy-

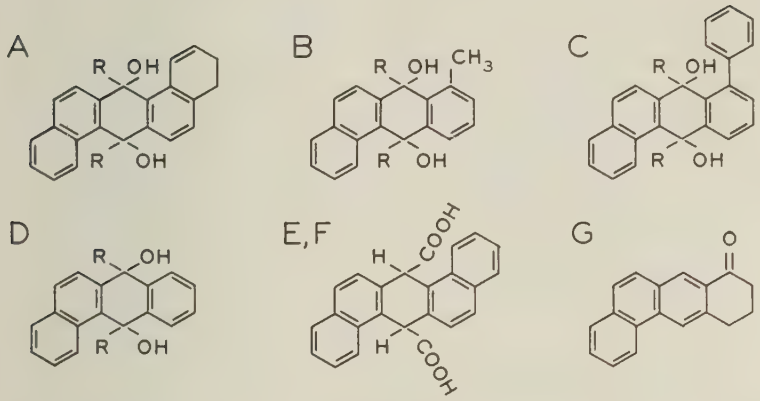

Fig. 1. Structural formulae of the compounds studied. *R* denotes an alkyl radical (methyl, ethyl, or propyl). Key letters are given for reference to the text

dro-5-methyl-1,2-benzanthracene; Formula B) differs from the first by the replacement of a benzene ring with a methyl group and is considerably less active. Injections of 0.5 mg. produced vaginal cornification which persisted for 2–4 days in seven rats. Only two of the five injected with 0.08 mg. responded. This substance appears more active in rats than in mice. Eight rats and seventeen mice were injected with oestrone on two successive days; the total dosage being 0.001 mg. of pure crystalline theelin.[1] All the mice responded, but only one of the rats. These animals were injected again later with a total dose of 0.25 mg. of the 5-methyl-dipropyl-diol (Formula B). Of the four rats injected subcutaneously two gave a full oestrogenic response and one only a partial response, while three out of four injected intraperitoneally gave a full response and the other only a partial; eight mice were injected subcutaneously and nine intraperitoneally; none of them responded. In another attempt four out of six mice responded to doses of 2.4 mg. intraperitoneally, but this dose was ineffective in all six mice injected subcutaneously. Rats were quite uniformly responsive to doses of 0.25 mg., whereas mice require dosages of at least 2.4 mg. to produce vaginal cornification even when given intraperitoneally. A greater sensitivity of the rat

[1] Pure crystalline theelin supplied through the kindness and generosity of Dr. Oliver Kamm of Parke, Davis and Co.

as compared to the mouse has been known for pregnancy urine prolan (Zondek, 1931). However, the more common oestrogens (oestrone, oestriol) have been shown to require larger doses in the rat than in the mouse.

The replacement of the methyl group of compound B by a phenyl group does not destroy its oestrogenic activity, as is shown in intraperitoneal assays of 9,10-dialkyl-9,10-dihydroxy-9,10-dihydro-5-phenyl-1,2-benzanthracene, Formula C. We have tried the compounds in which the dialkyl groups were methyl, ethyl, n-propyl, and n-butyl. The dimethyl compound was inactive in mice at dosages of 5 mg. Eight out of ten mice responded to 5 mg. of the diethyl, but only four out of ten responded to 5 mg. of the di-n-propyl. The di-n-butyl gave no effect at doses of 5 mg. Cook and others (1936) have studied the alkyl substitutions of the dibenzanthracene-diol (Formula A) and found the di-n-propyl much more active than the diethyl, but the dimethyl and the di-n-butyl were relatively inactive.

When the phenyl group is absent from compound C, as in 9,10-dialkyl-9,10-dihydroxy-9,10-dihydro-1,2-benzanthracene, Formula D, there is an enhancement of the oestrogenic activity. The dimethyl was inactive at 5 mg., whereas the diethyl was very active at 5 mg. and gave some effect at 0.8 mg. The dipropyl derivative has not been successfully prepared in a crystalline form. The material available probably had only one propyl group and was inactive at 5 mg. These compounds were tested only by intraperitoneal administration in mice.

The dimethylester of the compound (9,10-dicarboxy-9,10-dihydro-1,2,5,6-dibenzanthracene; Formula E) showed no evidence of oestrogenic activity at a dosage of 50 mg. In one of the three rats injected a sarcoma developed at the injection site. The water-soluble potassium salt of this compound (Formula F) was inactive in 10 mg. doses. Another preparation (5-keto-5,6,7,8-tetrahydro-1,2-benzanthracene; Formula G) was inactive in doses of 30 mg.

DISCUSSION

Certain of these synthetic compounds appear to be more oestrogenic in rats than in mice, which is the converse for the more common oestrogens such as oestrone or oestriol. When the oestrogenic bioassay method was first used it was assumed that it was a specific biologic response. With the advance in the chemistry of the sex

hormones it became apparent that the so-called female sex hormones existed in several chemical forms which were all closely related as oxidation and reduction products. However, it is now evident that many compounds not even closely related to the ovarian hormones are capable of producing comparable physiological results. These findings indicate that either the oestrous mechanism is very unspecific as compared with other biological processes or that all the compounds may be reduced to some more simple substance which is the active agent. It is hoped that a continuation of this study will help to clarify the chemistry of the oestrous mechanism.

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IDENTIFICATION AND DISTRIBUTION OF PNEUMOCOCCUS TYPES IN PNEUMONIA PATIENTS

EDITH B. HAMILTON

IN VIEW of the work done in the east and in the far west of this country, as well as of that abroad, on the incidence of pneumococcus types, it was thought advisable to make a comparative study of the types which occur in the Detroit area. The work was performed at the Detroit Receiving Hospital. This paper is a report of the results obtained during the period from March, 1935, to September, 1936.

In the first part of the study (March, 1935, to September, 1935) pneumococci were typed by using antipneumococcic serums of Types I, II, and III. The pneumococci which did not react to these serums were classified as Group IV. Later, however, we were able to separate Group IV into twenty-seven specific serological types by using serums of Types IV to XXXII, as suggested by Cooper and others. The serum for this work was supplied to us through the courtesy of the New York City Health Laboratory and the Lederle Laboratories, Inc.

METHOD OF TYPING

Except for a slight variation in the preparation of the sputum, the method of typing used was that of Neufeld (4). The whole sample of sputum, which was as large as possible, was shaken in a tightly stoppered bottle, together with saline and a dozen or more BB shot. The amount of saline and shot depended upon the size and the consistency of the specimen. This was for the purpose of making the sputum an easily managed emulsion. A drop of the prepared sputum was placed on a cover slip by means of either a wire loop or an opsonic pipette, and to this were added a drop of Löffler's methylene blue and a loopful of diagnostic antipneumococcic rabbit serum. The whole preparation was mixed with the wire loop

and inverted over a plain slide and then examined under an oil-immersion lens. When a homologous typing serum is used, the pneumococcus is easily recognized in such a preparation by the characteristic swelling of its capsule.

To facilitate the classifying of all thirty types of pneumococcus "pools" or groups of diagnostic serums are available, each pool containing from three to six individual types. In the technique described above the sputum is mixed with each group and examined microscopically after standing about ten minutes. If no reaction ensues in any of the groups, the specimen should be allowed to stand for at least half an hour. When a quelling occurs in any one of the groups, it is necessary to retype the sputum with the type serums which comprise the group. In this manner the individual type or types can be identified.

Pneumococci obtained from blood cultures, throat cultures, spinal fluid, and exudates were even more rapidly typed by the same method. When the specimen did not show enough pneumococci, it was injected intraperitoneally into a mouse, and after four hours the pneumococci in the aspirated peritoneal fluid were typed by the same Neufeld method. Occasionally, when no sputum was available, nasopharyngeal cultures, grown on dextrose brain broth, were used for typing. Later, however, we found that speed and accuracy were increased by centrifuging these broth cultures and using the sediment. The few throat cultures typed in the laboratory checked with samples of sputum obtained later, or when typings were done on material from autopsy.

DISTRIBUTION

Comparative occurrence of pneumococcic Types I, II, and III, as found in different and widely separated parts of the world, is shown in Table I.

From Table I it will be seen that, except in Rome and Detroit, Type I pneumococcic pneumonia occurs most commonly. In Detroit Type II seems to predominate. Generally speaking, Type III is relatively rare, and our findings closely compare with experience elsewhere.

The incidence of the various types found in pneumonia in the Detroit (Receiving Hospital) survey and their comparative occurrence in four widely separated cities in the world are shown in

Table II. In this survey 81 per cent of the pneumococci were isolated from patients with pneumonia. Of these cases (as shown in Table IV) 77 per cent were males and 23 per cent females. Of the total number there were nearly twice as many white (64 per cent) as black (36 per cent).

SUMMARY

In an interval of eighteen months, from March, 1935, to September, 1936, pneumococci were found in 779 patients, of whom 633 (81 per cent) had pneumonia. Contrary to the usual experience, we found that Type II pneumococci were most frequent, having been encountered in 117 cases (18.4 per cent). Type I occurred in 99 cases (16 per cent). The order of prevalence of a few of the other types was: Type VII, 5.8 per cent; Type III, 4.4 per cent; Type IV, 1.8 per cent; Type VIII, 1.7 per cent; Type V, 1.5 per cent. A slight modification for the preparation of sputum is described.

For advice and encouragement I wish to thank Dr. Osborne A. Brines and Dr. Alvin E. Price, under whose direction this investigation was made.

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TABLE I

Percentage of Incidence of Types and Location of Studies

Types	Boston (5) *	New York (1)	San Francisco (3)	Naples (6)	Rome (7)	Peiping (8)	Detroit
I	31	23	42.8	17	16.3	40.9	16
II	17	9	12.1	15	33.6	18.6	18.4
III	16	9	8.5	11	30.8	5.3	4.4
Number of cases. . .	857	397	322	131	140	158	633

* The numbers in parentheses refer to articles in Literature Cited.

TABLE II

PERCENTAGE OF COMPARATIVE OCCURRENCE OF PNEUMOCOCCI TYPES IV TO XXXII

Type	New York (2) *	San Francisco (3)	Peiping (8)	Detroit
				26.5 ‡
IV	11	0.9	1.6	1.8
V	12	2	18	1.5
VI †	6	1	5	0.4
VII	9.7	0.6	3	5.8
VIII	6.9	4.3	1.6	1.7
IX	3	2.4	11	0.9
X	2.3	0.3	5	0
XI	2.5	0.6	6	0
XII	2.3	0.3	1.6	0.2
XIII	2.5	0.3	1.6	0
XIV	5	1.2	15	1.2
XV	2.5	0.3	5	0
XVI	0.9	0.6	3	0.4
XVII	2.1	0.3	..	0
XVIII	3.9	0.3	..	0.3
XIX	3	0	3	0.6
XX	2.3	0.3	3	0.6
XXI	0.7	0.6	1.6	0
XXII	0.9	0	..	0.6
XXIII	1.6	0	6	0.3
XXIV	0.4	0	1.6	0.2
XXV	0.7	0.3	1.6	2.5
XXVII	0	0	1.6	0.6
XXVIII	0.2	0	..	0
XXIX	0.4	0	..	0.6
XXXI	0	0	..	0.3
XXXII	0	0	..	0.2
Unclassified...	9	19	..	12.3
Mixed types..	0	..	..	1.7
Total cases...	429	322	60	633

* The numbers in parentheses refer to articles in Literature Cited.

† A and B.

‡ Group IV.

TABLE III

Occurrence of Pneumococci in Sputum of Cases Other than Pneumonia

Type	Detroit	San Francisco	Peiping
I	5	3	..
II	6	0	..
III	15	8	..
IV	5	0	3
V	6	0	4
VI	3	3	15
VII	11	2	0
VIII	2	1	9
IX	6	1	3
X	3	2	9
XI	4	0	4
XII	2	0	3
XIII	3	0	6
XIV	5	1	2
XV	1	1	2
XVI	5	1	2
XVII	2	1	3
XVIII	6	0	4
XIX	6	3	7
XX	4	0	3
XXI	2	0	2
XXII	5	0	3
XXIII	0	0	10
XXIV	4	0	1
XXV	9	0	0
XXVII	0	0	0
XXVIII	4	0	1
XXIX	3	0	2
XXXI	3	1	1
XXXII	1	0	0
Mixed type.....	15	0	..
Total.....	146	28	99

TABLE IV

DISTRIBUTION OF PNEUMOCOCCIC TYPES ACCORDING TO SEX AND RACE

Type	Male	Female	White	Black
I	76	23	64	35
II	96	21	89	28
III	23	5	18	10
IV	9	3	5	7
V	8	2	4	6
VI	2	1	2	1
VII	32	5	17	20
VIII	8	3	7	4
IX	5	1	2	4
X	0	0	0	0
XII	1	0	0	0
XIII	0	0	0	0
XIV	6	2	4	4
XV	0	0	0	0
XVI	3	0	1	2
XVII	0	0	0	0
XVIII	1	1	2	0
XIX	3	1	3	1
XX	3	1	1	3
XXI	0	0	0	0
XXII	3	1	3	0
XXIII	2	0	1	1
XXIV	1	0	1	0
XXV	12	4	6	10
XXVII	2	2	4	0
XXVIII	0	0	0	0
XXIX	2	2	1	3
XXXI	1	1	1	1
XXXII	1	0	1	0
Unclassified....	53	25	38	40
Total...	353	104	275	180

TABLE V

MONTHLY INCIDENCE OF PNEUMOCOCCI

Type	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
I	4	5	2	2	14	4	21	5	10	11
II	7	5	10	9	13	11	6	8	15	6
III	2	2	3	4	4	2	7	3	3	..
IV	..	..	1	3	3	2	5	1	2	..
V	..	..	..	5	4	1	3	0	1	2
VI	..	..	..	..	3	..	..	2	..	..
VII	..	..	1	4	6	10	8	8	5	6
VIII	..	..	..	4	2	1	3	..	2	1
IX	..	..	..	4	2	2	..	2	2	..
X	..	..	..	1	..	..	..	2	..	..
XI	..	..	..	..	..	1	2	..	..	1
XII	..	..	..	1	..	..	1	..	1	..
XIII	..	..	..	..	..	..	2	..	1	..
XIV	..	..	..	2	4	2	2	3	..	..
XV	..	..	..	..	..	..	..	..	1	..
XVI	..	..	..	3	2	2	..	1	..	..
XVII	..	..	..	..	..	1	1	..	..	..
XVIII	..	..	..	12	1	..	3	1	..	1
XIX	..	..	2	1	1	..	2	2	1	1
XX	..	..	..	..	..	5	..	2	..	1
XXI	..	..	..	..	..	..	1	..	..	1
XXII	..	..	1	1	2	2	..	3	..	..
XXIII	..	..	..	..	..	..	..	1	..	..
XXIV	..	..	..	..	..	3	1	..	1	..
XXV	..	..	1	1	2	6	9	1	5	..
XXVII	..	..	..	..	..	1	3	2	..	..
XXVIII	..	..	..	..	2	1	..	..	..	1
XXIX	..	..	..	..	..	3	..	3	1	..
XXXI	..	..	..	..	..	..	..	5	..	..
XXXII	..	..	..	..	..	..	2	..	..	..

AN ANALYSIS OF HYBRIDIZATION IN A POPULATION OF STUNTED SUNFISHES IN NEW YORK

REEVE M. BAILEY AND KARL F. LAGLER

CERTAIN nominal species of sunfishes (Centrarchidae) and apparently aberrant individuals have been definitely shown by previous workers to be the result of hybridization. Sunfishes taken in nature have been determined as interspecific or intergeneric hybrids by Radcliffe (1914), McAtee and Weed (1915, pp. 12 13), Hubbs (1920; 1926, pp. 71 72), Hubbs and Ortenburger (1929*a*, pp. 19, 42–43; 1929*b*, pp. 49, 107), Osburn, Wickliff, and Trautman (1930, p. 169), Hubbs and Hubbs (1931, 1932, 1933), Greeley (1934, p. 107; 1936, p. 87), Greeley and Bishop (1933, p. 101), Thompson (1935), and perhaps others. Hubbs (1920), Hubbs and Hubbs (1932, 1933), and Breder (1936, pp. 20–21) have pointed out that the time and choice of breeding sites as well as a toleration for interspecific matings in nature produce most favorable conditions for hybridization. Finally, the hybrids reared experimentally in the laboratory (Hubbs and Hubbs, 1932, 1933) agree anatomically with natural specimens determined as hybrids, thereby establishing the actuality of hybridization in sunfishes. That such hybridization is not of extremely rare occurrence is indicated by the large number of specimens taken at numerous localities. To the eleven known hybrid combinations in the family Centrarchidae listed by Breder (1936, pp. 20–21) we may now add five more on the basis of specimens in the Museum of Zoology of the University of Michigan, i.e.: *Allotis humilis* × *Eupomotis gibbosus*, Illinois (reported also by Thompson, 1935); *Allotis humilis* × *Helioperca macrochira*, Kentucky (reported by O'Donnell, 1935); *Eupomotis microlophus* × *Helioperca macrochira*, Alabama; *Helioperca macrochira* × *Lepomis auritus*, Alabama and New York; and *Pomoxis annularis* × *Pomoxis sparoides*, Ohio and Illinois.

While working on the New York Biological Survey in the summer

of 1936 the authors encountered considerable numbers of hybrid sunfishes in a pond on the property of the Campfire Club of America, about one and one-half miles southwest of Millwood, Westchester County, New York. Some study was made of these hybrids in the field, and numerous specimens were kept for subsequent study. The fish fauna of the pond was found to be dominated by sunfishes. Of the three sunfish species in it *Eupomotis gibbosus* (Linnaeus) is a native inhabitant of sluggish waters in this region; *Helioperca macrochira* (Rafinesque) was very probably introduced, although it is now generally distributed in this area; and *Apomotis cyanellus* (Rafinesque) was almost certainly introduced. The last-named species, common in the Mississippi Valley and in parts of the Great Lakes system, was probably introduced into this pond accidentally during its stocking with bluegills from the United States Bureau of Fisheries in 1918; it is unknown elsewhere in the Atlantic drainage basin of New York except in the near-by Croton Reservoir, where it was probably introduced from the same source. Hybrid sunfishes of the three possible combinations, *Apomotis cyanellus* × *Eupomotis gibbosus*, *Apomotis cyanellus* × *Helioperca macrochira*, and *Eupomotis gibbosus* × *Helioperca macrochira*, were also found. The only associated species of fish were *Notemigonus crysoleucas crysoleucas*, *Perca flavescens*, *Anguilla bostoniensis*, and *Salvelinus fontinalis fontinalis* (the trout are stocked here each spring, but probably never survive throughout the summer).

This pond was formed in 1917 by damming a tributary of the Pocantico River, which flows into the Hudson River. It has an area of perhaps fifteen acres and a maximum depth of about seven feet. A maximum surface temperature of 90° F. was recorded during the hottest week of the summer of 1936, at which time the air temperature reached 102° F. The bottom is composed very largely of muck, decaying leaves, and other organic detritus. Parts of the inshore water are relatively shallow and have a gravel bottom that forms ideal spawning beds for sunfishes, but these are so small that there is serious crowding during the nesting period. This is probably responsible in large part for the lack of a normal ecological segregation of the species and, consequently, is most favorable for the production of an abundance of hybrids. Hubbs and Hubbs (1932, pp. 427–428) report this as a normal ecological condition where hybrids are commonly produced, but in this pond food conditions are poor in contrast

to the excellent food conditions which these authors noted as usual in ponds where hybrids abound.

Four hundred and sixty-three sunfishes were obtained in Collection 1, principally on or near the spawning beds, on July 9, 1936, when breeding was at its height. Most of the adult specimens taken were unspent, and males, the nest guardians, were present in greater numbers than females.

Collection 2, taken on July 25, 1936, comprised 873 specimens netted along the shore, where there was no concentration of nests. Spawning was well advanced at this time, although not entirely completed, and recently hatched young sunfish were common. These

TABLE I

Numerical and Proportional Distribution of the Species and Hybrids, and Sex Ratios

Species or hybrid	Collection 1					Collection 2					Collections 1 and 2		
	♂	♀	% of ♂	Total (463)	% of total	♂	♀	% of ♂	Total (873)	% of total	% of ♂	Total (1336)	% of total
Apomotis cyanellus.....	160	119	57.4	279	60.3	354	316	52.8	670	76.7	54.2	949	71.0
Eupomotis gibbosus....	37	7	84.1	44	9.5	59	32	64.8	91	10.4	71.1	135	10.1
Helioperca macrochira..	41	34	54.7	75	16.2	11	9	55.0	20	2.3	55.5	95	7.1
Apomotis × Eupomotis.	40	1	97.6	41	8.9	70	3	95.9	73	8.4	96.5	114	8.5
Apomotis × Helioperca.	20	0	100.0	20	4.3	13	1	92.9	14	1.6	97.1	34	2.5
Eupomotis × Helioperca	4	0	100.0	4	0.9	4	1	80.0	5	0.6	88.9	9	0.7

were so small as to make an accurate determination impossible, and they are not included in our count. So far as a seined shore sample can be representative of the fish population of a body of water, it is felt that this collection represents the relative abundance of the various species and hybrids. The catching of a number of additional specimens by hook and line in the deeper water indicates that larger individuals are present there than in the shoal waters. Table I gives for both collections the numerical and proportional distribution by species and hybrids, and the sex ratios.

Our objectives in this study have been as follows: (I) to note the degree of stunting of the fish; (II) to determine whether or not the increased growth of hybrids observed by Hubbs and Hubbs (1931) is maintained under conditions of stunting; (III) to check further the predominance of males among hybrids pointed out by Hubbs and

Hubbs (1933); (IV) to determine whether or not hybridization is indiscriminate or is most frequent in certain hybrid combinations; (V) to compare the characters of the hybrids and their parent species.

We are indebted to Dr. Emmeline Moore, in charge of the Biological Survey of the New York State Conservation Department, for the privilege of studying and reporting upon this material. Doctors Carl L. Hubbs, Albert H. Wright, George C. Embody, John R. Greeley, Ralph Hile, and H. J. Deason and Mr. Milton B. Trautman have our thanks for helpful suggestions and criticisms throughout the progress of the work. Mr. W. B. Greeley, of the Campfire Club, has kindly provided the dates of formation and initial stocking of the pond. The specimens are deposited in the New York State Museum and the Museum of Zoology of the University of Michigan. The age determinations were made by Lagler; the morphometric data were collected by Bailey.

I. STUNTING [1]

In Michigan (Hubbs and Cooper, 1935, pp. 672-676) stunting in *Apomotis cyanellus* and *Xenotis megalotis peltastes* has been shown to result from a shorter growing season and lower mean annual temperature. The same effect was noted upon the young of *Platygobio gracilis* as a consequence of a heavy infestation of parasites (Hubbs, 1927, pp. 79-80), and was accompanied by marked morphological changes.

In all species and hybrids of the material here reported upon we find a very marked reduction from normal growth rate, attended by bodily modifications: the eye is larger than normal; the body is narrower, especially in the dorsal region, which has a "razor-back" appearance; and dark longitudinal streaks run along the medial line of the scales on the side of the body. The sunfish population in this pond was extremely heavy, and competition for food was intense. There were relatively few aquatic organisms available as food, and any small object falling upon the water was immediately seized. Almost all the several stomachs examined contained large amounts of algae, supplemented by terrestrial insects, organic and inorganic débris, and, in the larger specimens, fish remains. If a fish attained a

[1] We prefer to employ the term "stunting" to designate an environmental effect resulting in decreased growth; "dwarfing" may be used to indicate a genetic effect.

size permitting a fish-eating diet the environmental restraint to growth was removed, for the available supply of both sunfishes and *Notemigonus* was enormous. A female *Apomotis* 206 mm. in standard length, in its tenth year of life, was caught in this pond on hook and line by Dr. C. Willard Greene. The largest hybrid specimen taken in our collections, a male *Apomotis* × *Eupomotis*, measuring only 115 mm., was in its seventh year, and the largest other fish, an *Apomotis*, a male 112 mm. long, was also in its seventh year. An examination of the scales of the 206 mm. *Apomotis* indicates that its growth was abnormally great during the later years of life, which tends to substantiate the view suggested above, that by feeding on other fish large specimens are able to overcome the stunting effect of earlier lack of nourishment. Considering the small available food supply and the avidity with which the fish took food, it seems very probable that decreased growth rate, emaciation, and other modifications are the direct results of malnutrition.

In support of this hypothesis we mention a specimen of *Eupomotis gibbosus* from Queensboro Lake, Rockland County, New York, which had a malformation that almost prevented opening the mouth. This fish showed extreme emaciation and an intensification of the various modifications noted above. Presumably the differences between it and its fellows were caused by its inability to eat a normal amount of food.

The type of abnormality shown by these stunted sunfishes is exemplified by the figures and the description of *Pomoxis barberi* Hildebrand and Towers (1928, pp. 126–130, Figs. 7 8), which, as Dr. Hubbs has determined (unpublished data), were based on undernourished specimens of *P. sparoides*. In other species of the family Centrarchidae, and in other families, the same abnormal features accompany malnutrition.

As an index to the amount of stunting in the population under treatment, Figure 1 A presents a comparison of the growth rate of the *Apomotis* from this pond with that given by Hubbs and Cooper (1935, p. 682, Table IX) for the same species in Michigan waters within the area characterized by a 150–180-day growing season. The New York pond lies in an area having a growing season of 175–190 days (Mordoff, 1934, p. 36, Fig. 46). Despite the longer growing season in this pond the growth rate is conspicuously retarded as compared with that of the Michigan fish. Further evidence of excessive

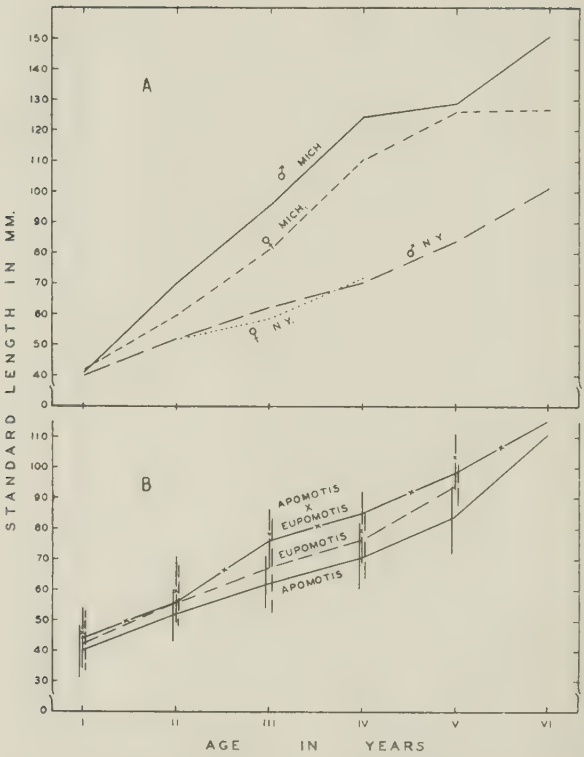

Fig. 1. Growth curves for sunfishes

A. Compares the growth of *Apomotis cyanellus* in the New York pond with that of the same species in southern Michigan

B. Compares the growth in the New York pond of males of *Apomotis*, *Eupomotis*, and the hybrids between these two genera

stunting is obtained by comparing the growth of *Eupomotis* females from the pond under consideration with that of specimens of the same sex taken on June 8, 1936, from the Hudson River at Kingston, for the vicinity of which a growing season of 160 days is indicated by Mordoff. Ten specimens from the pond had attained a mean standard length of 69 (65–78) mm. when taken, in their fourth summer of life, and thirteen from the Hudson River had reached a mean

size of 128 (121–141) mm. at the same age. Food and other growth conditions in the Hudson River at this location were excellent for sunfishes, barring possible deterrent effects from pollution.

II. GROWTH RATE OF THE HYBRIDS COMPARED WITH THAT OF THE PARENT SPECIES

Age determinations, the basis for growth-rate computations, were made by an examination of scales from all specimens of hybrids, *Eupomotis*, and *Helioperca* of both collections. In addition to all *Apomotis* specimens from Collection 1, some of the larger ones from Collection 2 were employed in order to give a greater representation of females in their fifth summer of life and of males in their sixth summer.

The mean lengths (to base of caudal) of each species and hybrid combination, together with the size range and the number of specimens on which the means are based, are listed in Table II. Repetition of the data for *Apomotis cyanellus* in this and succeeding tables facilitates a comparison of the hybrid combinations with their parent species.

Hubbs and Hubbs (1931, 1933) have indicated that hybrid sunfishes have an increased rate of growth as compared with that of the parent species. We find this condition to obtain for all age groups of the combination *Apomotis* × *Eupomotis* for which an adequate number of specimens is available. In none of the combinations do we find increased growth of the hybrids so pronounced as that observed in the same hybrid combinations by the workers cited. Comparison of the rate of growth of the male *Apomotis* × *Eupomotis* hybrids in Figure 1B with that of the males of each parent species shows a small but consistent accelerated growth of the hybrids. Although the numbers of specimens of the other hybrid combinations are not great enough to be considered dependable, the data for both the *Eupomotis* × *Helioperca* and the *Apomotis* × *Helioperca* hybrids seem to point to a growth rate which is more rapid than the mean growth rate of the parents. The growth rate of the hybrids of these two combinations is indicated as being almost as rapid as that of the faster-growing parent species. It is highly probable that under conditions of marked stunting increased growth of hybrids is conspicuously reduced, perhaps because the effects of heterosis on growth are thereby inhibited.

TABLE II

SIZE OF MALES AND FEMALES FOR EACH AGE GROUP OF EACH SPECIES AND HYBRID COMBINATION

There are indicated under each category the average length to base of caudal; the number of specimens, in subscript figures, on which the average is based; and, in parentheses, the range of variation in size to the nearest millimeter (measurements taken to tenths of millimeter).

Species or hybrid	Age group											
	I		II		III		IV		V		VI	
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Apomotis cyanellus	39.9_{48} (31–48)	39.9_{39} (35–48)	51.6_{43} (43–60)	51.7_{54} (45–60)	61.8_{29} (54–71)	58.9_{26} (54–70)	70.5_{34} (60–82)	71.9_{4} (66–82)	83.7_{9} (72–94)	.....	111.5_{1}	.....
Apomotis × Eupomotis	43.9_{48} (34–54)	.....	56.0_{27} (49–71)	56.9_{2} (52–62)	76.3_{8} (69–86)	71.4_{2} (67–76)	85.0_{8} (68–92)	.....	98.8_{17} (93–111)	.....	114.7_{1}	.....
Eupomotis gibbosus	41.8_{29} (33–53)	44.8_{12} (38–52)	55.8_{15} (48–68)	57.9_{16} (51–64)	67.4_{22} (52–83)	69.1_{10} (65–78)	76.1_{27} (63–85)	70.6_{1}	93.9_{2} (87–101)	.....	.....	.....
Eupomotis × Helioperca	.....	.....	.....	.....	72.8_{4} (62–77)	64.5_{1}	85.4_{2} (85–86)	.....	93.6_{2} (89–98)	.....	.....	.....
Helioperca macrochira	42.6_{25} (36–50)	42.1_{24} (36–49)	62.9_{8} (60–66)	63.3_{8} (55–69)	76.2_{10} (73–79)	71.7_{6} (66–77)	86.1_{9} (82–91)	77.8_{4} (76–79)	.....	96.6_{1}	.....	.....
Apomotis × Helioperca	45.6_{18} (36–49)	.....	59.3_{5} (49–68)	64.2_{1}	70.4_{9} (59–81)	.....	.....	.....	.....	.....	.....	.....
Apomotis cyanellus	39.9_{48} (31–48)	39.9_{39} (35–48)	51.6_{43} (43–60)	51.7_{54} (45–60)	61.8_{29} (54–71)	58.9_{26} (54–70)	70.5_{34} (60–82)	71.9_{4} (66–82)	83.7_{9} (72–94)	.....	111.5_{1}	.....

III. SEX RATIO [2]

The predominance of males in hybrid sunfishes has been indicated by Hubbs and Hubbs (1933, pp. 626–631). Our specimens show that males outnumber the females in each of the three parent species (Table I), but that the sex ratio is subject to no such marked deviation from an equal distribution as in the hybrids. A comparison of the sex ratios based on our material with data on the same hybrid combinations from various localities by Hubbs and Hubbs is given in Table III. In each hybrid combination our figures for Collection 1 show a higher percentage of males, due, perhaps, to their abnormally high proportion on the spawning beds. The sex ratios in Collection 2 agree rather closely with those given by Hubbs and Hubbs.

TABLE III

SEX RATIOS OF THE HYBRIDS

Hybrid	Hubbs and Hubbs			Collection 1			Collection 2		
	♂	♀	% of ♂	♂	♀	% of ♂	♂	♀	% of ♂
Apomotis × Eupomotis	295	17	95	40	1	97	70	3	96
Apomotis × Helioperca	47	11	81	20	0	100	13	1	93
Eupomotis × Helioperca	237	59	80	4	0	100	4	1	80

IV. IS HYBRIDIZATION INDISCRIMINATE?

In discussing whether or not hybridization is indiscriminate among these species it is assumed that the hybrids are sterile, a point held by Hubbs and Hubbs (1933) and supported by our material. For computations we use the specimens taken in Collection 2 (Table I) since, as explained on page 579, these alone may be considered a random sample of the population.

If hybridization among the species is indiscriminate we may expect to find that the hybrids of each of two species with the third species occur in the same relative numbers as do the parents of the

[2] The sex was determined by a gross examination of the gonads; in case of doubt the gland was teased out under the microscope.

first two species. For example, the ratio of the number of individuals of the hybrids $\frac{Apomotis \times Eupomotis}{Apomotis \times Helioperca}$ would be equal to the ratio of the individuals of $\frac{Eupomotis}{Helioperca}$, because the number of individuals of *Apomotis* which breed with the species of *Eupomotis* and *Helioperca* would be proportional to the available number of individuals of those two genera. If twice as many individuals of *Eupomotis* as of *Helioperca*

TABLE IV

Expected and Observed Number of Hybrids

Hybrid combination		Number of specimens	
One parent	Other parent	Expected	Observed
Apomotis	Eupomotis	71.3	73
	Helioperca	15.7	14
Eupomotis	Apomotis	75.7	73
	Helioperca	2.3	5
Helioperca	Apomotis	16.7	14
	Eupomotis	2.3	5

are present, we would expect twice as many hybrids of *Apomotis* × *Eupomotis* as of *Apomotis* × *Helioperca*. Now to determine the expected proportionate number of hybrids of each combination in the population, as sampled by Collection 2, we may use the formula:

$$\frac{A}{B} = \frac{K - Y}{Y},$$

in which

A = observed number of specimens of species a;
B = observed number of specimens of species b;
K = the sum of the observed number of hybrids of the two interspecific combinations of a third species, c, with a and with b;[3]
Y = expected number of hybrids of the interspecific combination $c \times b$, and
$K - Y$ = expected number of hybrids of the interspecific combination $c \times a$.

[3] It is valid and desirable to employ this figure, since its use does not affect the proportion between the expected numbers of hybrids, but causes the sum of the expected numbers of all hybrid combinations to equal the sum of the observed values, thus allowing ready comparison.

The expected values obtained by the use of this formula agree so closely with the observed numbers (see Table IV) that it is safe to conclude that the number of hybrids produced at this locality is in direct proportion to the numbers of the parent species. We may assume that the barrier to hybridization is neither a differential incompatibility of the germ cells in the three hybrid combinations nor a differential choice of heterogenetic mates.

V. DIFFERENTIAL CHARACTERS OF THE SPECIES AND HYBRIDS

Thus far no mention has been made of the determination of hybrids and parent species. Earlier workers have referred to the apparent intermediate character of hybrids between the parent species of Centrarchidae, but no detailed statistical comparison of hybrid sunfishes with their parent species has heretofore been published.

A comparison of the three forms and of the three hybrid combinations in regard to certain important differential characters is given in Table V. In *Apomotis*, *Eupomotis*, and the hybrid between them the opercle is rigid to its tip, excluding, of course, the membranous margin behind the posterior tip of the opercle. In *Helioperca* the tip of this bone is thin and flexible, and can be bent with very slight pressure of a dissecting needle. In the hybrids *Apomotis* × *Helioperca* and *Eupomotis* × *Helioperca* the opercle is semiflexible, that is, much more resilient than in *Eupomotis* and *Apomotis*, but less so than in *Helioperca*.

In *Apomotis* the opercular membrane has a broad border which is pale pinkish or faintly salmon-colored; in *Helioperca* the membrane is black to the tip; in the hybrids between these two it has a narrow gray border. *Eupomotis* has an intense scarlet-red spot on the membrane, and the hybrids between this genus and *Helioperca* have a smaller and more dilute spot of the same color on a dark membrane. The *Apomotis* × *Eupomotis* hybrids are likewise intermediate between their parent species, since they have a small and dilute scarlet-red spot on a pale margin. The red color is lost during the preservation of the fish, but the pattern remains as varying intensities of dark and light pigmentation.

A pronounced black spot at the base of the posterior soft dorsal rays is characteristic of *Apomotis*, but the spot in young specimens is occasionally faint. Neither of the other species shows a black spot

TABLE V

Differential Characters of the Species and Hybrids

Character *	Apomotis cyanellus	Apomotis × Eupomotis	Eupomotis gibbosus	Eupomotis × Helioperca	Helioperca macrochira	Apomotis × Helioperca	Apomotis cyanellus
1 Tip of operele	Rigid	Rigid	Rigid	Semiflexible	Flexible	Semiflexible	Rigid
2. Color of opercular membrane	Light margin	Small red spot on light margin	Red spot on margin	Small red spot on margin	Black margin	Dusky margin	Light margin
3. Basal posterior dorsal spot	Prominent	Faint or absent	None	None	None	Faint or absent	Prominent
4. Median posterior dorsal spot	None	None	None	Diffuse	Prominent	Diffuse	None
5. Light anal margin	Present, broad	Present, narrow	Absent	Absent	Absent	Present, narrow	Present, broad
6. Mouth size	Large	Moderate	Small	Small	Small	Moderate	Large
7. Length and shape of pectoral fins	Short, rounded	Moderate, bluntly pointed	Long, acuminate	Long, acuminate	Long, acuminate	Moderate, bluntly pointed	Short, rounded
8. Head length / Longest anal spine	3.3 (2.7–4.0)	2.7 (2.4 3.0)	2.3 (2.0–2.5)	2.1 (1.9–2.3)	1.9 (1.7 2.1)	2.4 (2.2–2.7)	3.3 (2.7–4.0)
9. Length of gill rakers †	Long	Moderate	Short	Moderate	Long	Long	Long
10. Palatine teeth	Many	Few	None ‡	None ‡	None ‡	Few	Many
11. Lower pharyngeal bones	Long and narrow; external margin straight; teeth slightly less acute than in *Helioperca*	Intermediate form; external margin slightly flexuose; teeth rather blunt	Broad and heavy; external margin a sigmoid curve; paved with bluntly truncate teeth	Intermediate form; external margin slightly flexuose; teeth rather blunt	Long and narrow; external margin straight; teeth sharply acute	Long and narrow; external margin straight; teeth acute	Long and narrow; external margin straight; teeth slightly less acute than in *Helioperca*

* Characters subject to direct count are treated in Tables VI–VIII. Some of these characters do not prove entirely valid for immature fish.
† The gill rakers become relatively shorter with age; this comparison is for fish of comparable sizes.
‡ The palatines may bear a single tooth, but are narrow and have no expanded dentigerous surface.

at this identical position, and the hybrids involving *Apomotis* show it either faintly or not at all. This character may be of simpler genetic composition than most others are, since it appears to be partly recessive.

In *Helioperca* there is a prominent black spot upon the median rather than the basal part of the posterior soft dorsal rays; the pigment is present on the fin rays and on the interradial membrane. No definite spot occurs in this position in *Apomotis*, or in *Eupomotis* or the hybrid *Apomotis* × *Eupomotis*, although in the last two numerous small pigment spots are scattered over the soft dorsal. In this character the hybrids *Apomotis* × *Helioperca* and *Eupomotis* × *Helioperca* appear intermediate between their parents. They have the dark pigment of the diffuse spot on the interradial membrane, but not on the fin rays.

The anal fin of *Apomotis* invariably shows a broad light margin, which is never seen in this area in *Eupomotis, Helioperca,* or their hybrid. This margin is present but somewhat narrower in both hybrids involving *Apomotis*, namely, *Apomotis* × *Eupomotis* and *Apomotis* × *Helioperca.* If we use this character alone it is possible to divide our specimens definitely into two groups: the first containing *Apomotis* and the two hybrids of which it is one parent; the second, *Eupomotis, Helioperca,* and the hybrid combination *Eupomotis* × *Helioperca.*

In *Apomotis* the mouth is much larger than in the two other species. Inversely, the pectoral fin is short in *Apomotis* and long in *Eupomotis* and *Helioperca.* These two characters are analyzed statistically in Tables IX and X. The pectoral fin, however, is a more diagnostic character than the length measurements alone indicate. In *Apomotis* the fin is rounded distally, rather than being sharply pointed, as in *Eupomotis, Helioperca,* and *Eupomotis* × *Helioperca.* The fin is rather bluntly pointed in the hybrids *Apomotis* × *Eupomotis* and *Apomotis* × *Helioperca.*

The fin spines are longest in *Helioperca* and shortest in *Apomotis.* The ratio of the length of the highest anal spine when stepped with dividers into the head length (including opercular membrane) is given in Table V. These measurements indicate that in this character the hybrids are roughly intermediate between their respective parent species.

The length of the gill rakers furnishes one of the best diagnostic

characters. Since the rakers of the anterior arch are relatively much longer in small specimens than in large ones, comparison should be made between fish of equal size. In specimens about 80 mm. long the longest gill rakers of *Apomotis*, *Helioperca*, and *Apomotis* × *Helioperca* are about four fifths as long as the pupil, or longer. In *Eupomotis* they are only about one third as long as the pupil; in *Apomotis* × *Eupomotis* and *Eupomotis* × *Helioperca*, about one half to three fifths as long. The hybrids appear to be entirely intermediate between the parents in each combination.

In *Apomotis* the palatine bones have a broad inferior surface which bears an elongate patch of many villiform teeth. In *Eupomotis*, *Helioperca*, and *Eupomotis* × *Helioperca* the inferior surface is merely a narrow bony ridge which is toothless or which bears one small tooth anteriorly. The hybrids *Apomotis* × *Helioperca* and *Apomotis* × *Eupomotis* have a narrow inferior surface which bears a small patch of villiform teeth anteriorly.

The pharyngeal arches and teeth are adequately treated in Table V; the hybrids of each combination are intermediate between their parent species.

By means of the combination of the various characters discussed above, we were able to identify all specimens with confidence. The smallest ones, over 30 mm. in standard length, had developed sufficiently to permit accurate determinations.

Certain additional characters have been selected for critical study in order to obtain a mathematical comparison of the species and their hybrids. These are listed below:

Counts:

Dorsal and anal fin spines
Dorsal and anal fin branched rays (posterior ray always considered double at the base)
Pectoral fin rays (all rudiments included)
Cheek scales (number of rows counted from eye to posteroventral angle of preopercle)
Lateral line scales (transverse scale rows on body to base of caudal rays)

Measurements:

Standard length (tip of snout to base of caudal rays)
Pectoral fin length (base of dorsal side of fin to tip of longest ray)
Upper jaw length (tip of snout to posterior tip of maxillary)

Measurements, taken with dividers and read to the nearest tenth of a millimeter, are reduced to thousandths of the standard length.

TABLE VI

FREQUENCY DISTRIBUTION OF VERTICAL FIN COUNTS IN THE SPECIES AND THEIR HYBRIDS

Figures in parentheses are the number of counts on which each mean is based.

Species or hybrid	Dorsal spines					Dorsal soft rays					Anal spines			Anal soft rays					
	9	10	11	12	Mean	10	11	12	13	Mean	3	4	Mean	8	9	10	11	12	Mean
Apomotis cyanellus	3	137	9	1	10.05 (150)	29	103	18	..	10.93 (150)	150	..	3.00 (150)	9	121	20	..	..	9.07 (150)
Apomotis × Eupomotis	3	105	6	..	10.03 (114)	7	91	16	..	11.08 (114)	113	1	3.01 (114)	1	69	43	1	..	9.39 (114)
Eupomotis gibbosus	1	115	18	1	10.14 (135)	2	69	63	1	11.47 (135)	135	..	3.00 (135)	1	13	102	19	..	10.03 (135)
Eupomotis × Helioperca	1	7	1	..	10.00 (9)	..	4	5	..	11.56 (9)	9	..	3.00 (9)	..	..	4	5	..	10.56 (9)
Helioperca macrochira	2	90	2	1	10.02 (95)	..	32	63	..	11.66 (95)	95	..	3.00 (95)	..	..	7	73	15	11.08 (95)
Apomotis × Helioperca	..	34	..	..	10.00 (34)	..	11	23	..	11.68 (34)	34	..	3.00 (34)	..	..	29	5	..	10.15 (34)
Apomotis cyanellus	3	137	9	1	10.05 (150)	29	103	18	..	10.93 (150)	150	..	3.00 (150)	9	121	20	..	..	9.07 (150)

Counts and measurements were made of all specimens of each species except *Apomotis cyanellus* and of each hybrid. For this species counts were taken of 150 specimens, and measurements of 328, including all available examples falling in the larger size groups. The counts for the sexes were combined, since they showed no difference.

A consideration of the frequency counts and the arithmetic mean values in Table VI indicates that there is no very significant variation in any form from the modal number of ten dorsal spines.

In dorsal soft ray count a slight but significant difference is noted between the species. The hybrid *Apomotis* × *Eupomotis* is intermediate between its parent species, but the mean is somewhat closer to that of *Apomotis* than to that of *Eupomotis*, since the difference is 0.15 ray rather than 0.39. In this feature *Eupomotis* × *Helioperca* hybrids are perfectly intermediate between their parent species. *Apomotis* × *Helioperca* hybrids have a mean 0.02 ray greater than

TABLE VII

Frequency Distribution of the Counts of Pectoral Fin Rays and Cheek Scales in the Species and Their Hybrids

Figures in parentheses are the number of counts on which each mean is based.

Species or hybrid	Pectoral rays					Cheek scales							
	12	13	14	15	Mean	3	4	5	6	7	8	9	Mean
Apomotis cyanellus	..	65	226	9	13.81 (300)	..	..	..	8	80	61	1	7.37 (150)
Apomotis × Eupomotis	..	59	162	6	13.77 (227)	..	..	21	86	7	..	..	5.88 (114)
Eupomotis gibbosus	11	243	15	..	13.01 (269)	4	126	5	..	..	..	..	4.01 (135)
Eupomotis × Helioperca	..	7	11	..	13.61 (18)	..	6	3	..	..	..	..	4.33 (9)
Helioperca macrochira	..	151	39	..	13.21 (190)	..	13	78	4	..	..	..	4.91 (95)
Apomotis × Helioperca	..	1	63	4	14.04 (68)	..	..	1	26	7	..	..	6.18 (34)
Apomotis cyanellus	..	65	226	9	13.81 (300)	..	..	..	8	80	61	1	7.37 (150)

Helioperca and 0.75 greater than *Apomotis*. This seems to suggest a complete dominance of the *Helioperca* parentage in this character, since there is no significant difference between the means for this species and the hybrid.

The number of anal spines is very constant, at 3; only one variant, with 4 spines, occurs in 537 specimens.

The differences in the number of anal soft rays between the species are more marked than those of any of the other fin elements. The

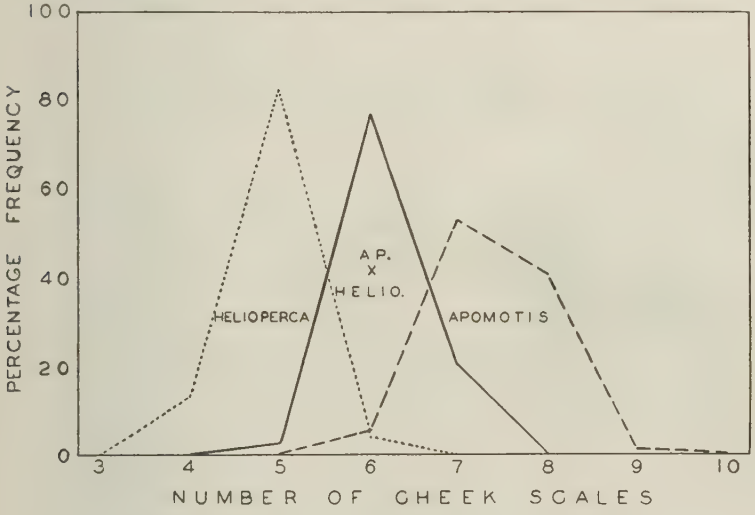

FIG. 2. Percentage frequencies of cheek-scale counts in *Apomotis*, *Helioperca*, and the hybrid combination *Apomotis* × *Helioperca*

hybrids *Apomotis* × *Eupomotis* have a mean value 0.32 greater than that for *Apomotis* but 0.64 less than that for *Eupomotis*. *Eupomotis* × *Helioperca* hybrids have a mean 0.53 greater than *Eupomotis* and 0.52 less than *Helioperca*. *Apomotis* × *Helioperca* hybrids have a mean 1.08 greater than *Apomotis* and 0.93 less than *Helioperca*. In these last two combinations the hybrids are almost uniformly intermediate between the parent species, but the *Apomotis* influence seems to be greater than that of *Eupomotis* in their mutual hybrid.

In all three hybrid combinations the pectoral ray count is higher than the mean of the counts for the parent species (Table VII). In

Apomotis × *Helioperca* and *Eupomotis* × *Helioperca* the means are significantly higher than in either of the parent species. The hybrid *Apomotis* × *Eupomotis* has a mean 0.76 greater than *Eupomotis* and 0.04 lower than *Apomotis*. This consistently increased number of pectoral rays is possibly related to the higher metabolic rate of the hybrids, which is indicated by the increased growth, more brilliant colors, and more pugnacious behavior of hybrid sunfishes as compared with the parent species.

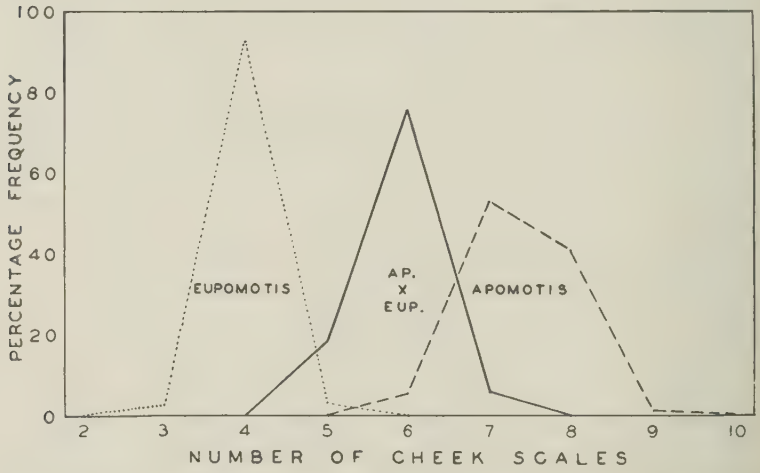

FIG. 3. Percentage frequencies of cheek-scale counts in *Apomotis*, *Eupomotis*, and the hybrid combination *Apomotis* × *Eupomotis*

The size of the cheek scales is one of the best criteria for comparing the hybrids and the parent species. As will be seen from Figure 2 and Table VII, the hybrid *Apomotis* × *Helioperca* is almost exactly intermediate between the parent species in the number of cheek scales. *Apomotis* × *Eupomotis* hybrids (Fig. 3) approach *Apomotis* slightly more than *Eupomotis*, since the respective differences of the means are 1.49 and 1.87. The small available number of *Eupomotis* × *Helioperca* hybrids is insufficient to enable us to obtain a satisfactory mean, but the one obtained is closer to that of *Eupomotis* than to that of *Helioperca*.

The counts of the scales in the lateral line (Table VIII) give results comparable to those of the cheek scales. The *Apomotis* × *Helio-*

perca hybrids (Fig. 4) have a mean 2.10 scales lower than the *Apomotis* and 2.19 higher than the *Helioperca*. The *Apomotis* × *Eupomotis* hybrids (Fig. 5) are not so exactly intermediate with respect to the parent species, since they have a mean 3.66 scales higher than *Eupomotis* and 3.34 lower than *Apomotis*. The nine specimens of *Eupomotis* × *Helioperca* have a mean value 0.99 scale lower than the *Helioperca* and 1.72 scales higher than the *Eupomotis*.

TABLE VIII

Frequency Distribution of Lateral Line-Scale Counts in the Species and Their Hybrids

Figures in parentheses are the number of counts on which each mean is based.

Species or hybrid	Lateral line scales																	
	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	Mean
Apomotis cyanellus	..	..	..	..	..	..	..	1	4	13	19	24	34	24	22	7	1	1	47.84 (150)
Apomotis × Eupomotis	..	..	..	2	3	7	10	9	21	27	14	12	7	2	..	..	..	..	44.50 (114)
Eupomotis gibbosus	2	5	8	17	21	35	27	7	7	1	2	2	..	..	..	..	..	..	40.84 (134)
Eupomotis × Helioperca	..	..	..	1	1	1	1	1	2	2	..	..	..	..	..	..	..	..	42.56 (9)
Helioperca macrochira	..	..	..	3	3	9	14	14	21	14	10	4	2	..	..	..	..	..	43.55 (94)
Apomotis × Helioperca	..	..	..	..	..	..	1	1	2	4	8	8	5	2	1	..	2	..	45.74 (34)
Apomotis cyanellus	..	..	..	..	..	..	..	1	4	13	19	24	34	24	22	7	1	1	47.84 (150)

Apomotis has a much larger mouth than have *Eupomotis* and *Helioperca*. Since female sunfishes of these species were found to have smaller mouths than the males, and since the hybrids are predominantly males, the sexes are considered separately. The size of the mouth increases with age, so that we have separated the fish into 10-mm. size groups. The mean lengths of the upper jaw, expressed in thousandths of the standard length, together with the

range of variation and the numbers of specimens on which the means are based, are given in Table IX for the species and the hybrids.

A comparison of the hybrids with their parent species of the same size group indicates that the hybrids are approximately intermediate between the parents, with the exception of irregularities due

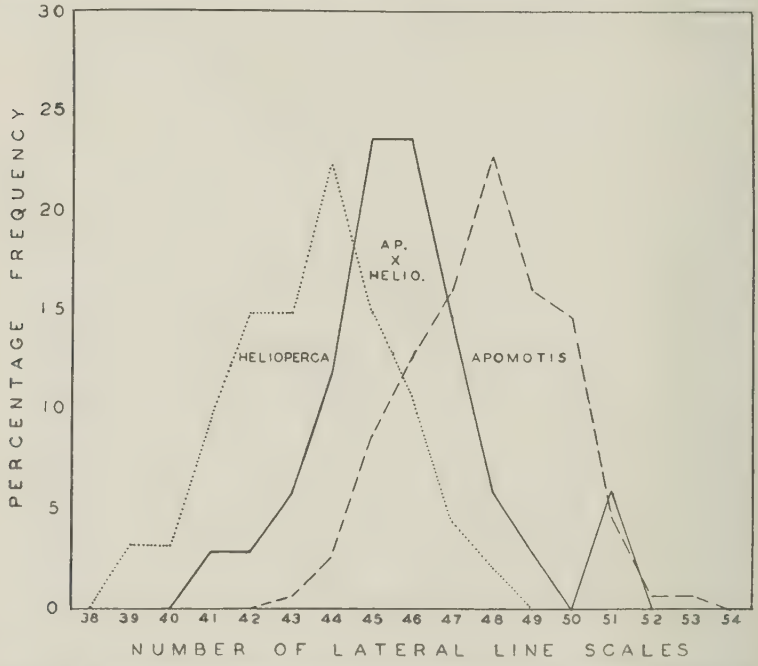

FIG. 4. Percentage frequencies of lateral line–scale counts in *Apomotis*, *Helioperca*, and the hybrid combination *Apomotis* × *Helioperca*

to an inadequate number of specimens. Obviously, the means based on the few female hybrids are of slight value. The total figures as given in Table IX are to be partly discounted because of the unequal distribution of specimens by size groups for the different species and hybrids. In all three species and in the hybrids the males have larger mouths than the females (Table IX). The difference is slight in *Helioperca*, but pronounced in *Apomotis* and *Eupomotis*. In the smaller size groups, which are composed largely of immature fish, the difference is not so great as in the larger size groups, consisting

of mature fish. There is a relative increase in the size of the mouth with age, most pronounced in *Apomotis* and slight in *Helioperca*. *Apomotis* × *Eupomotis* and *Apomotis* × *Helioperca* show a definite increase in size of mouth throughout life. The evidence, though not conclusive, indicates an increase in size of mouth in *Eupomotis* until a length of about 80 mm. is reached, and subsequently a decrease in proportion to the standard length.

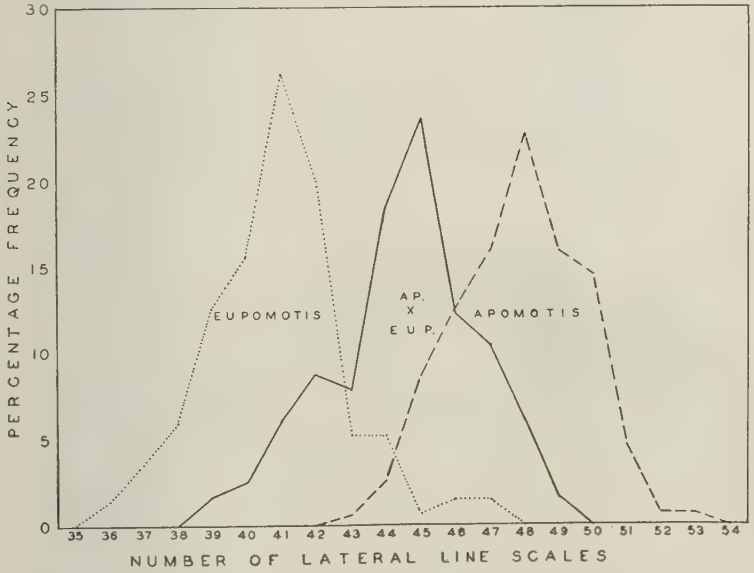

FIG. 5. Percentage frequencies of lateral line–scale counts in *Apomotis*, *Eupomotis*, and the hybrid combination *Apomotis* × *Eupomotis*

The relative length of the pectoral fin (Table X) is treated in the same manner as the length of the upper jaw. Except in size groups represented by an inadequate number of specimens, the mean pectoral length of the hybrid *Apomotis* × *Eupomotis* is approximately intermediate between *Apomotis* and *Eupomotis*. In the hybrid *Eupomotis* × *Helioperca* the pectoral length averages somewhat longer than in the parent species of the same size, but so few specimens are available that the increased length indicated may very probably be the result of an inadequate sample. The mean values for *Apomotis* × *Helioperca* are much closer to those for *Apomotis*

TABLE IX

MEAN UPPER JAW LENGTHS OF THE SPECIES AND HYBRIDS EXPRESSED IN THOUSANDTHS OF THE STANDARD LENGTH

The number of specimens on which each mean is based is given in subscript figures; the ranges of variation are in parentheses.

Size group in mm.	Sex	Apomotis cyanellus	Apomotis × Eupomotis	Eupomotis gibbosus	Eupomotis × Helioperca	Helioperca macrochira	Apomotis × Helioperca	Apomotis cyanellus
30.0–39.9	♂	141_{26} (132–146)	130_{9} (122–134)	110_{11} (106–124)	.....	109_{8} (107–111)	125_{1}	141_{26} (132–146)
	♀	139_{22} (131–147)	.....	102_{3} (98–103)	.....	108_{7} (100–111)	.....	139_{22} (131–147)
40.0–49.9	♂	147_{37} (138–156)	129_{37} (117–138)	109_{19} (92–119)	.....	107_{16} (102–113)	126_{18} (119–136)	147_{37} (138–156)
	♀	142_{35} (134–152)	.....	103_{8} (97–107)	.....	107_{17} (102–115)	.....	142_{35} (134–152)
50.0–59.9	♂	154_{37} (138–168)	135_{25} (129–141)	113_{13} (103–125)	.....	107_{1}	129_{4} (124–136)	154_{37} (138–168)
	♀	148_{53} (133–159)	128_{1}	105_{11} (99–114)	.....	105_{3} (104–107)	.....	148_{53} (133–159)
60.0–69.9	♂	165_{36} (148–181)	138_{6} (129–144)	115_{20} (103–127)	120_{1}	106_{7} (103–109)	132_{5} (129–135)	165_{36} (148–181)
	♀	151_{31} (137–164)	127_{2} (122–132)	105_{13} (96–119)	98_{1}	107_{7} (103–114)	120_{1}	151_{31} (137–164)

70.0–79.9	♂	170_{35} (155–185)	137_6 (130–148)	119_{23} (107–131)	116_3 (114–118)	112_{10} (105–133)	131_3 (124–135)	170_{36} (155–185)
	♀	156_1	125_1	111_4 (99–124)	.....	107_8 (104–110)	.....	156_1
80.0–89.9	♂	176_{11} (163–184)	145_6 (131–152)	115_9 (106–120)	117_3 (116–119)	114_7 (109–120)	138_2 (137–138)	176_{11} (163–184)
	♀	161_1	.....	.....	.....	.....	.....	161_1
90.0–99.9	♂	173_2 (169–176)	148_{16} (137–166)	.....	123_1	109_2 (107–111)	.....	173_2 (169–176)
	♀	.....	.....	.....	.....	110_1	.....	.....
100.0–109.9	♂	.....	152_3 (151–153)	111_1	.....	.....	.....	.....
	♀	.....	.....	.....	.....	.....	.....	.....
110.0–119.9	♂	179_1	155_2 (152–157)	.....	.....	.....	.....	179_1
	♀	.....	.....	.....	.....	.....	.....	.....
Total	♂	157_{185} (132–185)	136_{110} (117–166)	114_{96} (92–131)	118_8 (114–123)	109_{61} (102–133)	129_{33} (119–138)	157_{155} (132–185)
	♀	146_{143} (131–164)	127_4 (122–132)	105_{39} (96–124)	98_1	107_{43} (100–115)	120_1	146_{143} (131 164)

TABLE X

MEAN PECTORAL LENGTHS OF THE SPECIES AND HYBRIDS EXPRESSED IN THOUSANDTHS OF THE STANDARD LENGTH

The number of specimens on which each mean is based is given in subscript figures; the ranges of variation are in parentheses.

Size group in mm.	Sex	Apomotis cyanellus	Apomotis × Eupomotis	Eupomotis gibbosus	Eupomotis × Helioperca	Helioperca macrochira	Apomotis × Helioperca	Apomotis cyanellus
30.0–39.9	♂	269_{26} (253–287)	286_{9} (278–296)	303_{11} (279–333)	.....	310_{8} (296–329)	286_{1}	269_{26} (253–287)
	♀	266_{22} (257–292)	.....	301_{3} (282–324)	.....	308_{7} (284–325)	.....	266_{22} (257–292)
40.0–49.9	♂	266_{37} (246–289)	298_{37} (261–319)	315_{19} (282–332)	.....	320_{16} (308–335)	287_{18} (270–307)	266_{37} (246–289)
	♀	261_{35} (239–277)	.....	321_{8} (306–332)	.....	318_{17} (305–344)	.....	261_{35} (239–277)
50.0–59.9	♂	265_{37} (232–290)	298_{25} (265–320)	321_{13} (295–346)	.....	330_{1}	293_{4} (277–298)	265_{37} (232–290)
	♀	256_{53} (238–277)	251_{1}	319_{11} (290–340)	.....	344_{3} (331–357)	.....	256_{53} (238–277)
60.0–69.9	♂	268_{36} (249–289)	298_{6} (282–312)	341_{20} (318–371)	345_{1}	341_{7} (324–360)	290_{5} (273–300)	268_{36} (249–289)
	♀	261_{31} (244–286)	303_{2} (291–315)	328_{13} (310–348)	344_{1}	337_{7} (316–349)	268_{1}	261_{31} (244–286)

70.0–79.9	♂	265_{35} (240–295)	288_{6} (267–302)	341_{22} (300–373)	357_{3} (346–367)	349_{10} (324–376)	297_{3} (285 312)	265_{35} (240–295)
	♀	246_{1}	277_{1}	322_{4} (312–335)	.....	343_{8} (327–361)	.....	246_{1}
80.0 89.9	♂	261_{11} (247 275)	294_{8} (273–311)	331_{9} (306–361)	356_{3} (347–362)	357_{7} (342–371)	298_{2} (295–301)	261_{11} (247–275)
	♀	259_{1}	.....	.....	.....	.....	.....	259_{1}
90.0–99.9	♂	253_{2} (249–257)	295_{16} (276 315)	.....	353_{1}	341_{2} (332–349)	.....	253_{2} (249–257)
	♀	.....	.....	.....	.....	336_{1}	.....	.....
100.0–109.9	♂	.....	291_{3} (268–304)	309_{1}	.....	.....	.....	.....
	♀	.....	.....	.....	.....	.....	.....	.....
110.0–119.9	♂	249_{1}	294_{2} (281–307)	.....	.....	.....	.....	249_{1}
	♀	.....	.....	.....	.....	.....	.....	.....
Total	♂	266_{185} (232–295)	295_{110} (261–320)	327_{95} (279–373)	355_{8} (345–367)	333_{51} (296–376)	290_{33} (270 312)	266_{185} (232–295)
	♀	260_{143} (238–292)	284_{4} (251–315)	321_{39} (282–348)	344_{1}	326_{43} (284 361)	268_{1}	260_{143} (238–292)

than to those for *Helioperca*. This seems to suggest a partial dominance of the short pectoral fin of *Apomotis* over the long fin of *Helioperca*.

In all three species and all three hybrids the males have slightly longer pectoral fins than the females. In *Eupomotis* the proportionate length of the pectoral fin increases until a length of about 70 mm. is attained and then becomes shorter. In *Helioperca* the length of the fin increases proportionately until a size of about 90 mm. is reached, after which a slight decrease is indicated. In *Apomotis* the relative length of the pectoral seems to remain constant until a size of about 80 mm. is attained, after which a slight decrease is noted. In *Apomotis* × *Eupomotis* there seems to be no very great change during life, but in *Apomotis* × *Helioperca* the proportionate pectoral length increases gradually until the largest sizes are attained.

In order to enable us to secure a more concise comparison of the lengths of the upper jaw and of the pectoral fin in the hybrids and their parent species, the following method, developed by Dr. Ralph Hile, has been placed at our disposal. It involves comparison of two populations of the same sex and size group, and weights the significance of the mean difference observed according to the size of the product of the numbers of specimens used in determining the two mean values. The example given below, which compares males of *Eupomotis* × *Helioperca* with males of *Helioperca* in length of pectoral fin (data from Table X), will serve to illustrate the method of computation:

Size group in mm.	*Product of numbers of specimens*	*Difference in mean lengths of pectoral*	*Product of difference in mean lengths of pectoral × product of numbers of specimens*
60.0–69.9	7	− 4	− 28
70.0–79.9	30	− 8	− 240
80.0–89.9	21	+ 1	+ 21
90.0–99.9	2	− 12	− 24
	60		− 271

The average difference, − 271 60 = − 5, indicates that in the available material the *Eupomotis* × *Helioperca* hybrids have pectoral fins averaging five thousandths of the standard length longer than do the specimens of *Helioperca*.

The average differences for both upper jaw and pectoral fin lengths are given in Table XI. In the comparison of the species with one another the average difference between the males of any

TABLE XI

AVERAGE DIFFERENCES BETWEEN FISH OF THE SAME SIZE GROUP IN LENGTH OF UPPER JAW AND OF PECTORAL FIN, EXPRESSED IN THOUSANDTHS OF THE STANDARD LENGTH

The sign indicates the direction of change from the first to the second form compared, i.e.: a plus sign (+) preceding a figure indicates that the second named form has a greater average measurement than the first; a minus sign (−) preceding a figure indicates that the first named form has a greater average measurement than the second.

Populations compared	Average difference			
	Upper jaw length		Pectoral fin length	
	♂	♀	♂	♀
Apomotis : Eupomotis	− 44	− 43	+ 62	+ 62
Apomotis : Helioperca	− 48	− 37	+ 65	+ 63
Eupomotis : Helioperca	− 4	+ 2	+ 7	+ 8
Apomotis : Apomotis × Eupomotis	− 20	− 22	+ 30	+ 20
Apomotis × Eupomotis : Eupomotis	− 21	− 21	+ 25	+ 38
Apomotis : Apomotis × Helioperca	− 25	− 31*	+ 23	+ 7*
Apomotis × Helioperca : Helioperca	− 20	− 13*	+ 37	+ 69*
Eupomotis : Eupomotis × Helioperca	0	− 7*	+ 16	+ 16*
Eupomotis × Helioperca : Helioperca	− 5	+ 9*	− 5	− 7*

* Based on a single hybrid specimen.

two species closely approximates the difference between females of the same two species. The discrepancy in the length of the upper jaw between *Apomotis* and *Helioperca* and between *Eupomotis* and *Helioperca* is caused by the marked sexual dimorphism in the size of the mouth in *Apomotis* and *Eupomotis* and by the slight dimorphism in *Helioperca*. The comparison of the genera shows that *Apomotis* has a much larger mouth and a shorter pectoral fin than do *Eupomotis* and *Helioperca*. In males the mouth averages slightly larger in *Eupomotis* than in *Helioperca*, but in females is larger in *Helioperca*. Specimens of *Helioperca* have slightly longer pectoral

fins than those of *Eupomotis*. Too few female hybrids are available to enable us to obtain reliable average differences, but calculations on them are included for the sake of completeness. In males the differences between *Apomotis* × *Eupomotis* and each of its parent species in the length both of upper jaw and of pectoral fin are almost the same. These hybrids are approximately intermediate between the parent species, as are the *Apomotis* × *Helioperca* hybrids in respect to upper jaw length. As mentioned above, *Apomotis* × *Helioperca* is much closer to *Apomotis* than to *Helioperca* in length of pectoral, since the average differences are 23 and 37 respectively. The eight male *Eupomotis* × *Helioperca* hybrids are closest to *Eupomotis* in upper jaw length, but have longer pectoral fins than does either of the parent species.

Most characters of species of fishes are probably of multiple allelomorphic or blending rather than simple Mendelian inheritance. It is to be expected, then, that F_1 hybrids should be almost perfectly intermediate between their parent species in most if not all of their characters. It has been indicated that this condition holds for most of the characters here studied. The hybrids have been compared with the parent species in sixteen differentiating characters. In most of these characters the hybrids have proved to be approximately intermediate between the parent species. The basal spot in the soft dorsal fin of *Apomotis* gives the appearance of being nearly recessive since it is almost completely absent in the hybrid combinations of which it is one parent. The short pectoral fin length of *Apomotis* × *Helioperca* hybrids is interpreted as due to a partial dominance of the *Apomotis* character. The number of soft dorsal rays of *Apomotis* × *Helioperca* corresponds to that of *Helioperca*, and seems to indicate simple dominance of this character of *Helioperca* in the cross with *Apomotis*. *Apomotis* × *Eupomotis* hybrids approach *Apomotis* more closely than they do *Eupomotis* in both anal and soft dorsal ray counts. An increased mean number of pectoral rays in all three hybrid combinations is tentatively attributed to an increased metabolic activity and rate of development.

SUMMARY

1. Three hitherto unrecorded hybrid combinations are *Eupomotis microlophus* × *Helioperca macrochira*, *Helioperca macrochira* × *Lepomis auritus*, and *Pomoxis annularis* × *P. sparoides*.

2. A New York pond is abundantly populated by stunted sunfishes of three species, *Apomotis cyanellus*, *Eupomotis gibbosus*, *Helioperca macrochira*, and by the three possible hybrid combinations.

3. Intense crowding and competition for nest sites on the limited spawning area in this pond appear to be responsible for the large production of hybrids, which constitute 11.7 per cent of a large sample.

4. Adverse environmental conditions were responsible for a retarded rate of growth and for certain morphological modifications.

5. The phenomenon of increased growth in hybrid sunfishes is maintained under conditions of stunting, but is not so pronounced as in populations which may be considered normal.

6. That a predominance of males exists in hybrid sunfishes is further evidenced by the high percentage of males (80 to 96 per cent) in the sample studied.

7. Hybridization was indiscriminate among these species; therefore the barrier to hybridization was neither a differential incompatibility of the germ cells in the three hybrid combinations nor a differential choice of heterogenetic mates.

8. In most characters the hybrids are intermediate between their parent species.

9. The number of soft dorsal rays in the hybrid *Apomotis* × *Helioperca* indicates simple dominance of the *Helioperca* character in the cross with *Apomotis*. The basal spot in the soft dorsal of *Apomotis* is a partly recessive character. The short pectoral fin of *Apomotis* × *Helioperca* hybrids is probably due to a partial dominance of the *Apomotis* character.

10. An increased number of pectoral rays in the three hybrid combinations may be due to hybrid vigor.

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CONTRIBUTIONS TO TEXAN HERPETOLOGY

VI. NARROW-MOUTHED FROGLIKE TOADS (*MICROHYLA* AND *HYPOPACHUS*)

CHARLES E. BURT

THREE species of narrow-mouthed froglike toads occur in Texas. The two forms now referred to the genus *Microhyla* were formerly called *Gastrophryne*. Diagnosis is largely by the contrasts cited in the following key:

KEY

1. A poorly developed palmar tubercle at the base of the first toe of the hind foot; palmar tubercle at the base of the fifth toe of hind foot extremely rudimentary or absent; no light vertebral stripe 2

1. Well-developed palmar tubercles at the base of the first and fifth toes of the hind foot; a narrow light vertebral stripe or line sometimes present; southern Texas ..... *Hypopachus cuneus* Cope

2. Upper surface light greenish or gray, usually without dark blotches or other markings; Texas, except extreme eastern part
Microhyla olivacea (Hallowell)

2. Upper surface darker, often chocolate-colored or tan, usually blotched or with other dark markings; extreme eastern Texas
Microhyla carolinensis (Holbrook)

Microhyla carolinensis (Holbrook)

The eastern narrow-mouthed toad inhabits extreme eastern Texas, where it occurs in territory adjacent to that occupied by its very close western relative *olivacea*, with which it may be found to intergrade. Specimens have been secured one mile south of Maud, Bowie County (C. E. Burt, May 2, 1931); at Paris, Lamar County (Julius Hurter, April 21, 1895); and at Tenaha, Shelby County (Burt, July 21, 1936).

Microhyla olivacea (Hallowell)

Engystoma olivaceum Hallowell, 1857, p. 252 (type locality, Kansas and Nebraska).

Engystoma texense Girard, 1859, p. 169 (type locality, Rio Seco, Texas).

Engystoma areolata Strecker, 1909, p. 118 (type locality, Guadalupe River bottom, Victoria, Victoria County, Texas).
Gastrophryne texensis Stejneger and Barbour, 1933, p. 43.
Gastrophryne areolata Stejneger and Barbour, 1933, p. 43.
Gastrophryne olivacea Smith, 1934, p. 501.
Microhyla olivacea Parker, 1934, pp. 148, 201.

The determination of the status of *Gastrophryne areolata* has been a herpetological problem for some time; in an effort to reach a better understanding of the matter I have examined and compared many specimens of *Microhyla*. As a result of the study I am convinced not only that *areolata* should be placed in the synonymy of *olivacea*, but also that the differences between *carolinensis* and *olivacea* are not always clearly marked in the area where their ranges meet.

As a taxonomic derivative, *areolata* has never had a range apart from that of typical *olivacea*, both extremes appearing in a large series of narrow-mouthed toads collected near Victoria by J. D. Mitchell, in which a morphological gradient exists in the dorsal areolation and granulation. The type specimen of *areolata* shows a number of small elevations or tubercles and a weak and inconspicuous suturing or areolation of the skin of the back. These same general markings were observed far from the type locality of *areolata*, on living specimens of *olivacea*, in Dallas County on May 22, 1936. It may or may not be significant that the specimens of *Microhyla* with conspicuous dorsal tubercles of the *areolata* type are usually collected in the winter and spring months in which the breeding or the prebreeding season occurs, whereas the *olivacea* type is common in all months. Perhaps an increased roughness of the back of *areolata* is correlated with the progress of the annual sexual cycle in one of the sexes.

The skin of the somewhat softened type specimens of "*texensis*" in the United States National Museum is by no means perfectly smooth, since patches of poorly developed granulations and tubercles are discernible on the back. In summation, it may be stated that since the areolation, pustulation, width of body, and dorsal coloration of the skin of *Microhyla* vary widely in the series of specimens examined (including many eastern examples of *carolinensis*), *areolata* (as a species) appears to be indefinable and therefore inseparable from the general population of *texensis* (= *olivacea*), which it was originally said to "resemble in size and in the shortness of the hind

limbs." See Smith (1933) for a note on the synonomy of *texensis* with the previously described *olivacea*.

During the period of the year not concerned with breeding *olivacea* may be found in the eastern part of its area in Texas under the bark of fallen logs, or under the logs themselves, in the same general type of habitat as *carolinensis*: but in the typical part of its range in central and western Texas it usually rests under rocks, often away from woods or at their edge. An individual discovered in Erath County on March 17, 1934, was at the bottom of a tunnel under a rock. The burrow was very narrow and extended downward to a depth of about six inches.

On May 22, 1931, individuals were singing near Dallas. Here *olivacea* made a goatlike note as it clung to grass and weed stems at the point where they rose above the water of a small meadow pool. Upon slight disturbances these toads draw their snouts below the surface of the water and then dive to a new position, so that their capture is difficult.

I have examined the following specimens, including the two cotypes of *texensis* (U. S. N. M. No. 2644) and the type of *areolata* (U. S. N. M. No. 38999):

County	*Locality*	*Date*	*Collector*
Bastrop	5 mi. NW. McDade	June 5, 1935	C. E. Burt
Cameron	Brownsville	.....	R. D. Camp
Coleman	2 mi. W. Santa Anna	Sept. 4, 1935	Burt
Comal	3 mi. SW. New Braunfels	April 2, 1931	Burt
Dallas	2 mi. S. Dallas	May 22, 1931	Burt
Duval	San Diego	.....	W. Taylor
Erath	3 mi. NE. Dublin	March 17, 1934	Burt
Goliad	5 mi. NE. Fannin	April 5, 1931	Burt
Hidalgo	McAllen	June, 1916	D. D. Streeter
McLennan	Waco	April 22, 1910	J. Hurter
Medina	.....	June 3, 1909	J. D. Mitchell
Robertson	4 mi. SW. Hearne	June 4, 1935	Burt
Tom Green	South Concho River, 10 mi. S. San Angelo	April 25, 1931	Burt
Victoria	Guadalupe River bottom, near Victoria	Jan., 1909	Mitchell

Hypopachus cuneus Cope

Although *Hypopachus cuneus* resembles Texan *Microhyla* in appearance, direct comparisons of the two forms are very rare in the literature. Both specimens of *H. cuneus* at hand are 35 mm. in body

length, exactly the same as the toad from Lamar County that is identified and listed above as *Microhyla carolinensis*. The ratio of hind-leg length to body length of the two specimens of *H. cuneus* ranges from 1.08 to 1.14, whereas in *Microhyla* a range of from 1.07 to 1.14 is obtained for three examples of *olivacea* from Victoria County. Therefore, a distinction cannot be cited in relative leg length. In one type specimen of *H. cuneus* the back is roughened and much like that described for *M. areolata*, whereas in the other type specimen the back is smoother, thus approaching the more "typical," smooth-backed examples of *M. olivacea* and *M. carolinensis*, so that there may be a parallel development in the tuberculation and the areolation of the back in the two genera — and this may be correlated with the sexual cycle as suggested above in the discussion of *M. olivacea*.

The specimens of *H. cuneus* in the United States National Museum are from Brownsville, Cameron County (R. D. Camp), and San Diego, Duval County (William Taylor, a cotype).

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FURTHER STUDIES OF PERCH POPULATIONS *

R. WILLIAM ESCHMEYER

INTRODUCTION

A GROUP of lakes in the Pigeon River State Forest, in Otsego and Cheboygan counties, Michigan, is being used by the Institute for Fisheries Research for experimental studies in fish management. These small lakes, thirteen in number, are located on state-owned land. Certain of them are remarkably similar in their general characteristics. At the time of the Institute's original survey of these lakes in 1931 and 1932 they were found to contain a very limited fish fauna. They were little frequented and resembled virgin waters more nearly than any other group of lakes in the Lower Peninsula.

After the preliminary biological, physical, and chemical survey of these waters in 1931 and 1932 a number of experimental studies involving environmental changes and alterations in the fish fauna were made, particularly on a group of eight small lakes which are known locally as "pothole" lakes and which fit almost perfectly the description of pit lakes as given by Scott (1921). These eight lakes all have thermal stratification, all have high, steep, sandy banks, all but one are almost perfectly circular in outline, and all but one are landlocked.

In four of the lakes the survey party found only perch (except that one also yielded a few common suckers). Two of the others apparently contained only brook trout and minnows. In the other two only forage fish were found. The trout taken from the two lakes were of uniform size and, according to Mr. William Horsell, superintendent of the forest, had been introduced in 1927. The four lakes containing perch provided little or no fishing because the perch apparently were too small to be worth catching; the two lakes with

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation and the University of Michigan.

no game fish were obviously not fished; the two lakes that had been stocked with trout provided excellent fishing.

As a result of the findings of the survey party it was recommended that all eight lakes be stocked with brook trout. The recommendations were carried out in 1933 and 1934. It was found later that four lakes provided some good trout catches, but that the four lakes which contained perch still failed to produce worth-while fishing. Several of these lakes were fished with gill nets to determine the success of the stocking with trout. Apparently few trout had survived in the lakes which contained perch and those which had survived had grown very slowly.

As a further attempt to improve the fishing in the "perch" lakes several environmental changes were considered: (1) increase of the food by fertilizing; (2) removal of a considerable portion of the perch population, and (3) complete removal of the perch followed by stocking with some other species. If lack of food alone limited the growth, fertilization might be expected to increase the number of fish of legal size; if either competition or scarcity of food or crowding was responsible, fishing should be improved by removal of a large percentage of the stock.

One of the lakes was fertilized with several hundred pounds of phosphate fertilizer. The fish in the other three lakes were killed by poisoning (coupled with dynamiting in two of them), and the lakes were later stocked with other species. For methods employed my earlier paper (1937) may be consulted. This paper is confined chiefly to a study of the fish which were collected in three of the lakes after the poisoning.

Some characteristics of one of these populations (that from South Twin Lake) have already been described (Eschmeyer, 1937). It was found that in this lake perch grew very slowly and were in very poor condition. The females grew more rapidly than the males and lived longer. Males, however, were the more numerous. Over three fourths of the fish belonged to a single age group (II group). The evidence suggested further that most of the perch normally died of starvation before reaching legal size.

The discussion which follows includes primarily a consideration of some of the characteristics of the recently studied perch populations (from Ford Lake and Section Four Lake), together with a comparison of these populations with the South Twin Lake fish. The collections

of all three groups of fish were made in lakes in the same general vicinity and at the same time of year (in consecutive years). The methods used in killing and collecting the fish were the same for each lake except that dynamite was not used in Section Four Lake.

THE FORD LAKE FISH POPULATION

Ford Lake lies in Section 8, Township 32 North, Range 1 West, in the northeastern corner of Otsego County. A survey of the lake in 1932 by the Institute revealed an area of 11.7 acres (4.73 hectares) and a maximum depth of 10 meters. In summer the water is definitely stratified, with the thermocline between the depth of 5 meters and the bottom. The bottom soil in shoal is varied (sand in some areas, marl or peat in others) and in deeper water is entirely peat. The water is moderately clear (Secchi disk reading 5.5 meters) and is alkaline (pH 8.2). Dissolved oxygen was present at all depths (9.4 p.p.m. at surface, 8.6 p.p.m. at bottom on August 1, 1932). This landlocked lake is in sandy country covered by "second-growth" timber. The drainage area is small.

In September, 1936, the water level was considerably lower than at the time of the 1932 survey. The lake was resurveyed by Mr. J. B. Schwerdt, project superintendent of Camp Vanderbilt (U. S. Parks Service), and the area was determined as 10.66 acres. This determination is used below in the discussions of population density.

The yellow perch was the only species of fish taken in gill-net and seine collections made in Ford Lake by the survey party in 1932. These perch were mostly small. If fish other than perch were present, they were apparently quite rare, since the lake was fished rather intensively. So far as could be determined, the lake supported little angling.

Ford Lake was stocked with trout on several occasions in an effort to improve fishing conditions. The years in which plants were made and the number, species, and size of the fish are shown in Table I.

Gill nets were fished in this lake in 1934, and the entire population (apparently) was killed by poisoning and dynamiting in 1936. It was obvious in 1936 that the trout plantings had not been very successful. After the fish had been removed, the lake was stocked with Montana grayling.

Both the fish recovered by netting in 1934 and those taken by poisoning and dynamiting in 1936 are discussed below.

TABLE I

STOCKING RECORDS FOR FORD LAKE, 1933–35 *

Year	Species	Number	Age when planted	Average size in inches when planted
1933	Brook trout	500	8 months	4
1934	Brook trout	6,000	6 months	3¼
	Brown trout	600	8 months	3½
	Rainbow trout	600	Yearlings	5
1935	Rainbow trout	300	Adults (3 years old)	12–15

* Data provided by Mr. Guy Lincoln, district superintendent of fisheries operations, Oden Hatchery.

Fish Taken in 1934

A total of 1,137 perch and 15 brook trout were taken in two experimental gill nets [1] fished continuously from July 23 to July 30. The trout were not preserved and were not measured. Their estimated average total length was 6 to 7 inches. Some of the perch were discarded, but a random sample of 602 specimens was preserved in a 10 per cent solution of formalin.

Sex determinations were made of all the preserved fish. Determinations of weight, length, and age were made for a random sample of 100 individuals. The average standard length and average total length in millimeters, the average weight in grams, and the average coefficient of condition (K) [2] of each age group in each sex are shown in Table II.

If the 100 specimens constituted a representative sample of all the perch taken in gill nets, the following conclusions may be made regarding the Ford Lake perch population:

Sex. — The two sexes were about equally represented. Of the 602 specimens, 298 were females, 304 were males.

Growth. — The females grew more rapidly than the males. In all age groups represented (except age group I) the fish of both sexes

[1] The sizes of mesh (stretched measure) in the nets varied from 1¼ to 4 inches.

[2] The formula $K = \frac{W \times 10^5}{L^3}$ was used, where W = weight in grams and L = standard length in millimeters.

TABLE II

AVERAGE STANDARD LENGTH (MILLIMETERS), AVERAGE TOTAL LENGTH (INCHES), AVERAGE WEIGHT (GRAMS), AND AVERAGE CONDITION FOR A RANDOM SAMPLE OF FEMALE AND MALE PERCH OF DIFFERENT AGES

All specimens were taken in July, 1934, by gill nets.

Age group	No. of specimens	Average standard length (mm.)	Average total length (inches)	Average weight (grams)	Average *K*
Females					
II	19	113	5.3	24	1.67
III	27	115	5.4	26	1.68
IV	7	123	5.8	31	1.65
Total or average	53	115	5.4	26	1.67
Males					
I	1	108	5.2	22	1.75
II	19	110	5.2	23	1.70
III	27	111	5.2	22	1.62
Total or average	47	111	5.2	22	1.65

had a very slow growth. (See Table II.) The growth zones of the scales of all age groups indicated that growth was moderately good during the first year and generally during the second year. After the second year the annual growth increments were small. It is probable that this change in growth resulted from a lack of food of a size suitable for larger perch.

Weight. — The perch had an average weight of 24 grams, or slightly less than one ounce (entire sample of 100 fish).

Condition. — The perch were in relatively good condition. The value of *K* decreased slightly as the age increased, but this decrease was probably too small to be significant. In general, condition varied little with either sex or age.

Length of life. — The sample suggests that the females tend to live longer than the males. Seven of the 53 females were of the IV group, but the oldest of the males were of the III group. This sex difference in longevity is in accord with findings of other studies of perch (Schneberger, 1935; Eschmeyer, 1937).

Total weight of sample. — If the average weight of the perch is assumed to be 24 grams, the number removed (1,137) had a total

weight of 27,288 grams (60.2 pounds), or a weight of 2,560 grams (5.6 pounds) per acre.

The ratio of trout to perch in 1934 (15 : 1137) was approximately 1 : 76. A computation of the fish removed in 1936 indicated a total population of approximately 5,000 perch at that time. If about the same number was present in 1933, the ratio of trout to perch immediately after the planting of 500 trout in 1933 was about 1 : 10. Apparently the number of trout in the population had declined very materially between 1933 and 1934, unless the difference in the two ratios (1 : 76 and 1 : 10) was due to net selectivity.

Gill nets were fished in 1934 in an effort to reduce the population, since there appeared to be a scarcity of food for the number of perch present, especially food of intermediate or large size (minnows). The perch removed in 1934 represented approximately 24 per cent of the perch recovered in 1936. It was, of course, impossible to determine what percentage of the fish present in 1934 had been removed.

Not only was the food per fish increased by the removal of some of the perch, but a total of about 15,500 forage fish was planted in July, 1934. These fish were taken from a small stream where it had been impounded by beaver. Most of them were northern dace (*Chrosomus eos*), although limited numbers of fathead minnows (*Pimiphales promelas*), sticklebacks (*Eucalia inconstans*), mud minnows (*Umbra limi*), and perhaps a few fish of some other species were also present.

Fish Taken in 1936

On the morning of September 9, 1936, Mr. W. F. Carbine and the writer, assisted by men from Camp Vanderbilt, poisoned the waters of Ford Lake with 200 pounds of powdered derris root (5 per cent rotenone content) mixed with water. On the afternoon of the same day recovery of the dead fish was facilitated by discharging 500 sticks of dynamite in the water. The fish began to die within about an hour after the poisoning. The collection of the dead fish was started immediately and was continued for three days. On the third day 183 dead perch were counted along the shore, but were not collected because of their semidecomposed condition.

It is probable that all the fish were killed, and it is also probable that almost all the perch were either collected or counted. (In two

other lakes where weaker concentrations of derris root had been used the entire perch population had been destroyed. Nets set in these lakes in 1936 failed to produce fish.) How many dead fish remained in deep water in Ford Lake is not known, but over that part of the bottom which could be seen from a boat (about a third of the entire area) no dead perch were observed other than the 183 specimens mentioned above. The evidence, therefore, though not conclusive, suggests that all fish were killed and that almost all the perch were definitely accounted for.

Total Fish Population

A collection of 3,762 perch was preserved in a 10 per cent solution of formalin and 1,055 perch were discarded. At least 4,817 perch are therefore definitely known to have been present. Computations based on the average weight of 1,050 specimens taken at random give an estimated weight of 347 pounds for the total perch population.

A total of 24 rainbow trout and 1 brown trout were preserved and 2 trout (partly decomposed) were discarded. These trout had a combined weight of 7 pounds (provided the 2 trout discarded were of average weight).

Dead minnows lined the shore, especially along the wave-swept side. On two representative 10-foot sections of shore line the dead minnows were counted by Dr. A. S. Hazzard and Mr. Carbine. According to the counts made, the lake shore contained 15.3 minnows per linear foot of shore line. Ford Lake, with an area of 10.66 acres, would have a circumference of about 2,400 feet if it were exactly circular. The exact length of shore line was not determined, but since the outline of the lake is roughly circular, its length may be estimated at that figure. On this basis the lake had contained approximately 36,700 minnows. Weight determinations of 61 specimens of minnows gave an average weight of about 2 grams. The minnows, therefore, weighed approximately 73,400 grams or 162 pounds. The weight of minnows per acre was about 15 pounds.

The total fish population in 1936 was approximately as follows:

	Pounds
Perch.....	347
Trout.....	7
Minnows....	162
Total.....	516

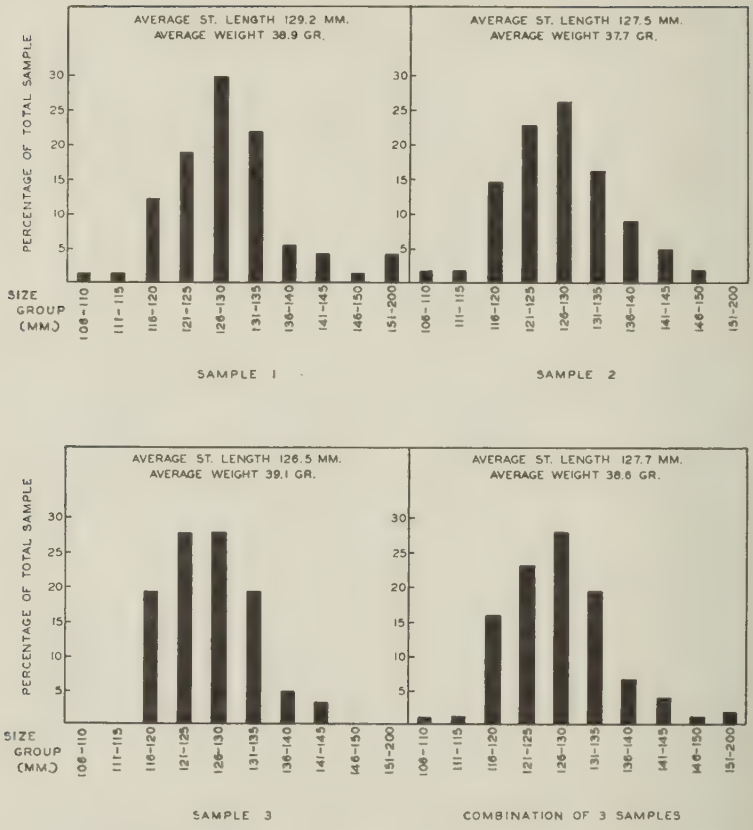

FIG. 1. Size distribution of 205 females in three lots of perch taken at random and also in the three lots combined

The lake therefore maintained about 50 pounds of fish per acre.

The first important evidence obtained from the collections was that the plantings of trout in Ford Lake were not very successful. A total of 8,000 trout had been planted since 1933, but only 28 were recovered in 1936 (and 15 in 1934). Relatively few were removed by fishermen. Some may have remained on the bottom at the time of the poisoning, but it seems safe to conclude that the survival from trout plantings in the lake was very slight. The few which were recovered were in relatively poor condition.

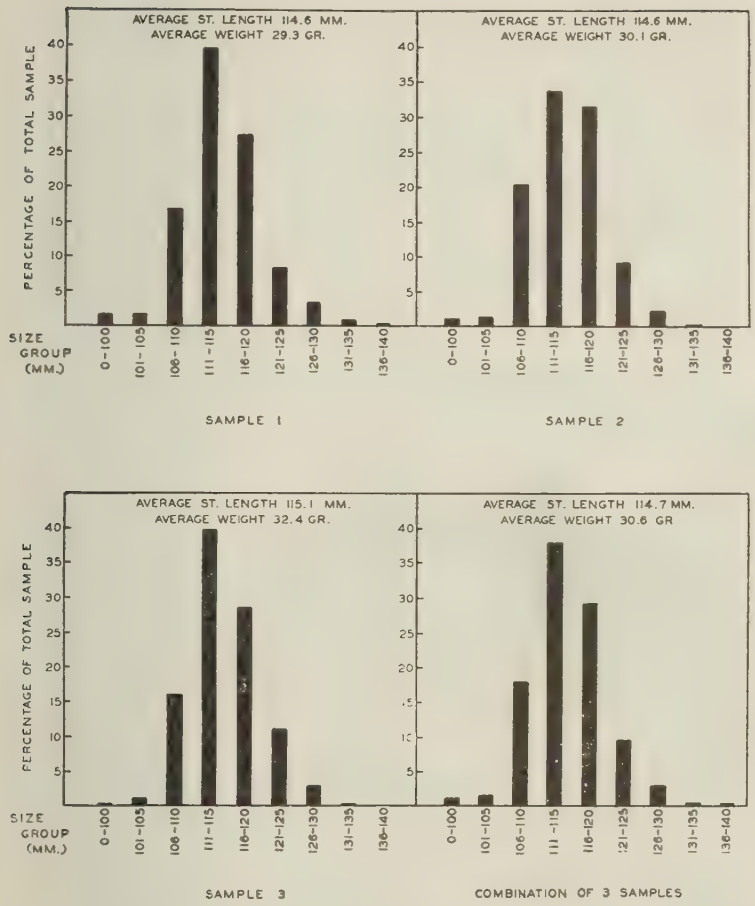

FIG. 2. Size distribution of 845 males in three lots of perch taken at random and also in the three lots combined

Because of the apparently unfavorable balance between fish and food at the time the minnows were stocked (in 1934) it was not expected that any of the species would become established. It was assumed that the minnows would soon be eaten by the perch. The minnows did serve as a food item for the perch, but evidently enough survived for them to become definitely established. All

species except sticklebacks known to have been stocked in 1934 were found in 1936. The number of minnows had apparently doubled in the two years.

The large number of perch in the collection made the use of samples advisable. Sex determinations were made for all the 3,762 preserved perch, but the data on length and weight are based on three samples of 350 fish each, taken at random. The close similarity of the data obtained from each of these three samples (Table III and Figs. 1–2) demonstrates that the results obtained from their combination (1,050 fish) may be considered representative for the entire population. In further discussions of length and weight it is assumed that the averages for the three samples (845 males and 205 females) represent the averages of the entire population. The error which might be involved in using these samples rather than the entire populations is obviously small.

TABLE III

AVERAGE STANDARD LENGTH (IN MILLIMETERS) AND AVERAGE WEIGHT (IN GRAMS) FOR THREE RANDOM SAMPLES OF FEMALE PERCH AND THREE RANDOM SAMPLES OF MALE PERCH AND FOR COMBINATIONS OF THE THREE SAMPLES (205 FEMALES, 845 MALES)

Sample	Average standard length (mm.)	Average weight (grams)
Females		
Sample 1	129.2	38.9
Sample 2	127.5	37.7
Sample 3	126.5	39.1
Combination of 3 samples	127.7	38.6
Males		
Sample 1	114.6	29.3
Sample 2	114.6	30.1
Sample 3	115.1	32.4
Combination of 3 samples	114.7	30.6

Size Distribution

The length distribution for each sex is shown in Figures 1–2 and in Table IV. The distribution of both male and female perch approaches a normal curve, but fails to indicate more than one age group except for the suggestion of a second group of males (at 71–80

millimeters) represented by a very few individuals. On the average, the females were 13 millimeters longer than the males.

TABLE IV

Length Distribution of 205 Female Perch and 845 Male Perch by Five-Millimeter Classes (Standard Length)

Length group (millimeters)	Females		Males	
	Number	Percentage of total	Number	Percentage of total
71–75	..	....	2	0.2
76–80	..	....	2	0.2
81–85	..	....	...	....
86–90	..	....	1	0.1
91–95	..	....	...	....
96–100	..	....	4	0.5
101–105	..	....	12	1.4
106–110	2	1.0	150	17.8
111–115	2	1.0	319	37.8
116–120	32	15.6	245	29.0
121–125	47	22.9	81	9.6
126–130	57	27.8	24	2.8
131–135	39	19.0	4	0.5
136–140	13	6.3	1	0.1
141–145	8	3.9	...	....
146–150	2	1.0	...	....
151–155	2	1.0	...	....
156–160	..	....	...	....
161–165	1	0.5	...	....
Total	205	100.0	845	100.0
Average standard length	127.7 mm.	....	114.7 mm.	....

Age Determinations

An effort was made to determine the ages of the 1,050 fish in the three samples. For some reason not known to the writer the annuli beyond the second year were very difficult, often impossible, to locate with certainty. After repeated efforts the attempt to determine the ages was abandoned except for approximately 150 specimens. Even on these it is not certain that the annuli were invariably counted correctly. Annuli were more easily located on the perch taken from Ford Lake in 1934 than on those taken from the same lake in 1936.

The size, weight, and condition of these fish as determined for the different age groups are shown in Table V.

TABLE V

Length, Weight, and Condition of Perch of Each Sex, by Age Groups, Based on a Study of 149 Specimens

Age group	Number of specimens	Average standard length (mm.)	Average total length (inches)	Average weight (grams)	Average *K*
Females					
II	1	116	5.51	37.8	2.42
III	21	127	5.98	37.0	1.83
IV	4	130	6.14	41.1	1.88
V	1	131	6.30	41.7	1.85
Total or average (females)	27	127	5.98	37.8	1.86
Males					
0	1	90	4.06	14.0	1.92
I	1	111	5.31	32.9	2.41
II	7	113	5.35	29.2	2.00
III	90	116	5.51	32.7	2.08
IV	23	119	5.63	35.3	2.11
Total or average (males)	122	116	5.51	32.8	2.07

The position of the first two annuli showed that the growth was reasonably good during the first year and, in most specimens, during the second year, but growth was very poor in all succeeding years. The data on age groups II, III, and IV (Table V) suggest that the females grew more rapidly than the males. Fish of the III group apparently predominated, although fish of the IV group were fairly well represented. Young fish (0, I, and II groups) were scarce.

The approximate number of legal-sized perch of each sex was determined. All fish 150 mm. or more in length were regarded as legal-sized fish (6 inches or 152.4 mm. total length). Since all fish had been preserved before measurements were taken, some shrinkage undoubtedly occurred. The shrinkage factor 1.016 determined by Van Oosten (1929) for lake herring was used. Of the 845 males examined 44 (5.2 per cent) were of legal size, and of the 205 females 140 (68.3 per cent) were of legal size. Since the entire population of

4,817 perch (sexes were determined for 3,762 fish) was estimated to contain 3,572 males and 1,245 females, the total number of legal-sized fish in the lake included approximately 186 males and 850 females. The ratio of females to males in the lake was approximately 1 : 3, but the ratio of legal-sized females to legal-sized males was over 4 : 1. The only age groups whose average lengths were above the 6-inch legal limit were the IV and V group females.

It might be argued that the lake contained more males than females because few legal-sized males were taken by the fishermen, whereas a majority of the females were of legal length. The lake was fished so little, however, that this argument does not hold.

Sex Ratio

In the perch taken by gill nets in 1934 the two sexes were about equally divided. Nets, as stated earlier, were again set in Ford Lake just before the poisoning in 1936 and were lifted immediately after the poisoning operations had been completed. The fish taken in the nets were inadvertently placed with the dead fish collected, and consequently the sex ratio of the gill-net sample could not be determined. It was noted later, however, that of those fish having gill-net marks about half were females. It may be stated with assurance that the gill nets were highly selective with respect to the sexes, probably because most of the males were too small to be caught in them.

The 3,762 perch which were preserved consisted of 2,791 males and 971 females. There were 34.8 females per 100 males or approximately a 1 : 3 ratio. A fourth of the perch (25.8 per cent) were females. It is improbable that the percentage of females changed from about 50 per cent in 1934 to 25 per cent in 1936. It is more likely that the perch taken in gill nets set in 1934 were not representative, with respect to the sex ratio, of the fish which were then present in the lake.

Food

No investigation was made of the food available for the fish, but the stomach contents of 100 males and 100 females, taken at random, were examined. This study was especially interesting because it showed a difference in the food of the two sexes.

A fourth (25) of the stomachs from females contained minnows.

They were in various stages of digestion, and obviously many had been eaten before the poisoning. The stomach of one female contained a partly digested perch. Eight stomachs from females contained a half-dozen or more winged ants. It is probable that a flight of these ants had crossed the lake just before the poisoning and that ants were not ordinarily available in abundance as food. Twenty-four stomachs contained *Corethra* (mostly larvae) and 22 contained chironomid larvae. Other food organisms, including Ephemeridae, Amphipoda, Odonata, Coleoptera, Phyllopoda, and Trichoptera, were present in relatively insignificant numbers. Seventeen stomachs were empty.

Of the 100 stomachs from males only 3 contained minnows. Several ants were found in another. *Corethra* occurred in 31 stomachs, and Chironomidae in 14. Odonata, Ephemeridae, Phyllopoda, Amphipoda, and Cladocera were found in a very few stomachs. Over a third (36) of the stomachs were empty.

Death by poisoning is relatively rapid, and it is possible that the proportion of empty stomachs is representative of normal conditions.

It may be stated that minnows constituted the chief food of the females and that *Corethra* larvae were the chief food of the males. Earlier in the summer, when the young minnows were smaller, they may have served as an important food organism for the male perch also. The decided increase in the condition (K) and the slight increase in growth in 1936 over 1934 may have resulted from the introduction of minnows in 1934 or from reduction in population by netting.

Distribution of the Sexes within the Lake

The Institute's lake-survey parties have frequently observed that perch removed from their nets were mostly of one sex. Often catches of 50 or more were all of one sex. Members of the parties who failed to recognize this peculiarity often doubted for a while their ability to determine the sex of perch, despite the fact that the structure of the gonads makes sex determination of individual perch relatively simple. Since the sexes have different rates of growth, the dominance of one sex in the net may depend, partly, on net selectivity. It has been noted, however, that even in line fishing the fish taken may be largely of only one sex. It would seem, therefore, that, to some extent at least, the two sexes tend to school separately. Since such schooling

appears to take place during all or most of the summer, it is seemingly not connected with spawning. The food study offers further evidence of the schooling in separate sexes and gives a plausible reason for such segregation. The minnows were apparently normally in shallow water, and the ants were very probably floating on the surface. Since these two food items were prominent in the stomachs of the females, it appears probable that many of the females were feeding in shallow water. The males, on the contrary, were apparently in deeper water, where they fed primarily on midge larvae. In Ford Lake, at least, a difference in the distribution of the two sexes can be explained on the basis of the differences in the distribution of their favorite food organism. Differences in growth rate of the sexes account for differences in feeding habits of fish of the same age. Whether similar situations are to be found in other perch populations remains to be determined.

SECTION FOUR LAKE

Section Four Lake, Town 32 North, Range 1 West, is a pothole lake that is similar in many respects to South Twin Lake. According to the Institute's survey in 1932, it has an area of 3.3 acres and a maximum depth of 21.7 meters. The outline is almost perfectly circular, and the basin is bowl-shaped, with very little shoal area. In summer the water is definitely stratified, with a thermocline at 4–11 meters (August 1, 1932). The bottom soil on the shoal and the slope is marl, and in deeper water is peat. The water is relatively clear (Secchi disk reading 6.8 meters) and is alkaline (surface pH 7.9). The survey showed (August 1, 1932) that the dissolved oxygen is high at the surface and in the thermocline (11.1 p.p.m. at 8 meters), but is low near the bottom (1.8 p.p.m. at 14 meters; trace at bottom). This very small landlocked lake has high, steep, sandy banks and an extremely small drainage basin.

The survey records indicate that only perch were taken in the gill-net and seine fishing in 1932. It is doubtful whether other fish were present at that time. In 1932, and again in 1934, when a few perch were taken in gill nets, the fish were small (seldom over 6 or 7 inches long) in all samples.

Section Four Lake seemed well suited for trout except that here, as in the other landlocked lakes in the area, the trout could not, of course, be expected to maintain themselves by natural reproduction.

In 1933 Oden Hatchery officials stocked this lake with 300 brook trout eight months old. In 1935 the lake (after removal of the perch) was stocked with 150 adult rainbow trout.

On September 19, 1935, Dr. A. S. Hazzard and the writer distributed approximately 75 pounds of powdered derris root (5 per cent rotenone content) over the lake. The first dying fish were observed one and one-half hours after the introduction of the poison. Collecting of the dead fish was begun immediately and continued, at intervals, for the next fifty hours. Dead perch were still coming to the surface when the party left. Nets set in this lake a year later (September, 1936) produced no perch. It seems, therefore, that all perch were killed. Not all were collected, however.

Total Population

A total of 1,736 perch (526 per acre) were recovered. These fish had a combined weight of 76.36 pounds or a weight of 23.1 pounds per acre. The actual number and weight of the fish present were, of course, in excess of these figures.

TABLE VI

LENGTH DISTRIBUTION OF PERCH FROM SECTION FOUR LAKE BY CENTIMETER INTERVALS (STANDARD LENGTH)

The dotted line approximately divides the undersized and the legal-sized fish.

Length group (millimeters)	Both sexes	Females	Males
49.5–59.5	1	1	...
59.5–69.5	91	40	51
69.5–79.5	322	142	180
79.5–89.5	34	9	25
89.5–99.5	90	18	72
99.5–109.5	250	50	200
109.5–119.5	592	53	539
119.5–129.5	246	124	122
129.5–139.5	72	60	12
139.5–149.5	27	26	1
149.5–159.5	7	7	...
159.5–169.5	3	3	...
169.5–179.5	1	1	...
Total	1,736	534	1,202

TABLE VII

NUMBER OF FEMALE AND MALE PERCH IN EACH YEAR GROUP, AND AVERAGE LENGTH, WEIGHT, AND CONDITION OF FISH *

Item	Age group				
	0	I	II	III	IV
Number of fish:					
Females	192	82	171	82	7
Males	255	149	786	12	..
Total (both sexes)	447	231	957	94	7
Average standard length (mm.):					
Females	72.8	104.7	123.5	136.9	157.9
Males	76.5	100.0	115.2	131.3	....
Average weight (grams):					
Females	6.2	17.2	28.6	41.0	63.1
Males	6.0	15.8	24.3	34.4	....
Average total length (inches, approximate):					
Females	3.5	4.9	5.8	6.5	7.4
Males	3.6	4.8	5.4	6.2	....
Average weight (ounces):					
Females	0.2	0.6	1.0	1.4	2.2
Males	0.2	0.55	0.9	1.2	....
Average value of K:					
Females	1.66	1.53	1.54	1.59	1.60
Males	1.36	1.63	1.60	1.53	....

* Since these fish were taken in mid-September they were actually almost one growing season older than the figures (annuli) indicate.

Size and Age Distribution

All perch recovered were measured to the nearest millimeter and weighed to the nearest tenth of a gram after several months' preservation (first in 10 per cent formalin and later in 70 per cent alcohol). The 0 group fish were weighed in lots of 20–50 each; all other fish were weighed individually. The length distribution, by centimeter groups, is shown in Table VI. No really large perch were taken. The data suggest the presence of at least two age groups.

The ages of approximately 50 per cent of the fish were determined by a study of the scales. Many of the perch of the 0 and II groups could be placed in their age groups without examination of the scales.

This method of separating these two age groups was used for about half of these fish. If any error was involved, it was slight, for subsequent scale examination proved the ages estimated for several hundred fish to be correct.

In contrast with the perch from South Twin Lake and Ford Lake, most of the fish in Section Four Lake (Table VI) were young. The II group, which was represented by 957 specimens, comprised over half of the fish taken, but both the 0 group and the I group were also well represented. Only age groups III and IV, represented by a total of 101 specimens, averaged legal size (6 inches).

The females were larger than the males in all except the 0 group. Young fish were dominantly males, but the fish in the III group were 87 per cent females and all fish in the IV group were females (Table VII). Most of the legal-sized fish were females.

Sex Ratio

The ratio of males to females was 100 : 44 or approximately 2 : 1. Because the lake was fished very little this predominance of males cannot be attributed to the fact that most of the legal-sized perch were females and therefore more subject to capture by fishermen.

Condition

The perch of all age groups were in fair condition, except that the males in the 0 group were relatively slender. In general, the K varied little for the several age groups. The females tended to improve slightly in condition after the first year, but the averages of K for males decreased slightly with increase in age.

SOME CONCLUSIONS REGARDING THE THREE PERCH POPULATIONS

This summary is based on data for the two populations discussed above and for the South Twin Lake population described in an earlier paper (Eschmeyer, 1937). All three populations were removed in September, one in each of the years 1934, 1935, and 1936. Derris root was used to poison the fish in all three lakes, and dynamite was employed after the poisoning in two of them.

Total Populations

The fish of the two lakes which were both poisoned and dynamited were probably almost all collected or seen. The population was

approximately 30 pounds per acre in the lake with very little shoal (South Twin), and about 50 pounds per acre in the one with extensive shoal. The numbers of perch actually accounted for varied from 452 per acre in Ford Lake to 955 per acre in South Twin Lake.

Size and Age Distribution

The perch grew slowly in all three lakes. Their growth, except for the first year, was slower than the growth of perch for other waters as determined by Harkness (1922), Hile (1931), Jobes (1933), and Schneberger (1935). Comparative growth data are presented in Table IV of the study of the South Twin Lake perch (Eschmeyer, 1937). Since the other authors removed only a portion of the fish, data on comparative population densities are not available. It seems probable, however, that the populations from the three lakes in the Pigeon River State Forest were more dense than were those in the other lakes studied.

From a fishing standpoint, all three lakes were of little value. Some of the perch in each lake (5.8 per cent in Section Four Lake to 21.5 per cent in Ford Lake) were of legal size (6 inches), but very few had a length of 7 inches.

In two of the three lakes the young age groups (0 and I) were almost entirely absent. It is possible that most of the young perch of those lakes had been eaten by the larger fish.

In all three lakes the females grew more rapidly than the males. The females also tended to live longer. The oldest fish were invariably females.

In general, the perch grew very slowly after their first or second year of life. This slow growth is attributed to a scarcity of food organisms of moderate size (except in Ford Lake in 1936), but it is possible that the concentration of fish, rather than the food supply, may have been responsible for the slow growth.

Sex Ratio

Males predominated in all three perch populations. The ratios of males to females for each lake were: South Twin Lake, 100 : 74; Section Four Lake, 100 : 44; and Ford Lake, 100 : 35. The reason for the differences in the sex ratio in the three lakes has not been found. It cannot be attributed to the selective capture of females in sport fishing since all the lakes were fished very little. The lake with

the fish in poorest condition had twice as many females per 100 males as the lake containing perch in the best condition. Whether or not the greater viability of the females in the face of adverse conditions (Geiser, 1924) explains this difference cannot be stated. The predominance of males suggests that, in the early stages, the females tended to suffer a much greater mortality than the males unless, of course, the sexes were not equally represented in the fish immediately after hatching. In later years, however, the mortality of males exceeds that of the females.

Condition

The perch in South Twin Lake were in very poor condition; those in Ford Lake were in excellent condition. The average of K for Section Four Lake perch was intermediate. Nevertheless all three populations grew quite slowly. The condition of these fish was therefore not correlated with their rate of growth. Apparently the fact that a fish is in good condition is not an indication that it is also growing rapidly.

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ANALYSIS OF THE FISH CATCH FOR ONE YEAR IN THE WATERLOO PROJECT AREA*

ALBERT S. HAZZARD AND R. WILLIAM ESCHMEYER

INTELLIGENT management of the fishing in any area requires: (1) an adequate survey of physical, chemical, and biological characteristics of the waters; and (2) a "creel census" of the representative waters continued over a period of years.

A survey is essential to determine the conditions for the species of fish present and the need for environmental improvements; also, to ascertain whether the existing game species require encouragement by plantings and whether introduction of new species is desirable to improve the fishing.

A complete census of the fish yield is necessary to evaluate the benefits of environmental improvements and fish stocking, as well as to demonstrate fluctuations in the yield of game fish under existing regulations. Such a census in the Waterloo Area [1] will be particularly valuable in showing the effect of winter fishing upon summer fishing, the type of fishing practiced, and any changes in the character or the intensity of the fishing which may come about as the development of this area proceeds. At present the lakes in the Waterloo Project are used principally by anglers from near-by counties, but as organized camps are completed and facilities for other kinds of camping are improved, it is almost a certainty that the fishing pressure will increase, and thus necessitate greater efforts on the part of the agency responsible for maintaining the fish supply; hence the importance of a census at this time and of continuing such a project.

The Institute for Fisheries Research proposed survey and census projects for the Waterloo Area (National Parks Service) when, in 1934, its coöperation in the development of the fishing was requested.

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation and the University of Michigan.

[1] A submarginal area in Jackson and Washtenaw counties, Michigan.

The creel census was started immediately and, except for a short period, has been continuous. A detailed survey of the lakes was carried on by the Institute, assisted by the personnel of the Waterloo Project, during the summer of 1936. The results of this investigation will be reported in a subsequent paper.

The census was secured by selected crews of local employees of the Area. These men were coached in methods of taking data and were checked frequently for accuracy and completeness of their records. Each census clerk was responsible for a certain section of shore line or, where the area was small, for an entire lake. Upon leaving the lake anglers were asked to display their catch and to report on methods employed, period fished, number of undersized fish caught, etc. For a more complete description of the methods used in creel census studies see Eschmeyer (1936).

All labor and immediate supervision of the census were provided by the Waterloo Project. The Institute assisted in an advisory capacity and later tabulated, summarized, and interpreted the information obtained.

The census of winter fishing was not complete for the season, but extended from January 6 to 19 and from February 21 to March 31. A continuous record of the fish yield was secured from the opening of the summer season, June 25, to the time of ice formation, November 30.

The lakes where this census was conducted and their approximate areas are as follows:

	Acres [2]		*Acres* [2]
Cassidy	36	Big Portage	480
Clear	136.7	Cedar	56
Green	78.3	Crooked	70
Mill	204	Doyle	10
Mirror	4	Mud	64
Sugarloaf	204.8		
Walsh	10.2		
Waterloo Mill Pond (lower)	10.5		

According to reports, the other lakes in the Waterloo Project supported little or no fishing except Trist Mill Pond, which was not

[2] Areas listed in the first column are based on plane-table survey and are quite accurate; those in the second column were determined from the United States Geological Survey maps and are only approximate.

covered by the census. Waterloo Mill Pond (lower) was only partly covered, but is included in the discussion. The information obtained from the census is discussed separately for winter fishing and for summer fishing. The catches during the two seasons are then compared and the effect upon the total fish population is calculated.

WINTER FISHING

The combined area of the twelve lakes under observation during part of the winter was approximately 1,308.5 acres. It was reported that five of these lakes (Cassidy, Doyle, Green, Mirror, and Walsh) were not fished. Information on the catch in the other seven during a 54-day period is shown in Table I.

It will be noted that winter fishing was negligible on all except

TABLE I

INFORMATION ON WINTER FISHING (1936) ON SEVEN LAKES IN THE WATERLOO AREA FOR THE PERIODS JANUARY 6–19 AND FEBRUARY 21 — MARCH 31 (54 DAYS)

Data summarized	Lake								
	Clear	Crooked *	Mill	Mud	Portage	Sugarloaf	Waterloo Mill Pond (lower)	Total	Percentage of total
Number of fisherman days	499	6	18	18	364	11	12	928	..
Number of fish caught (total)	3,881	3	6	4	1,349	5	29	5,277	..
Catch per hour	1.7	0.1	0.1	0.1	0.8	0.1	..	..	..
Large-mouthed bass	1	..	..	..	2	..	..	3	tr. ‡
Black crappie	3,493	..	..	..	330	4	6	3,833	73
Bluegill †	25	..	..	..	46	1	6	78	1
Common sunfish †	..	..	..	..	250	..	..	250	5
Perch	313	..	..	4	62	..	10	389	7
Rock bass	..	..	..	..	552	..	..	552	10
Walleye	..	..	..	..	1	..	..	1	tr.
Northern pike	48	3	6	..	71	..	3	131	2
Gar	..	..	..	..	5	..	4	9	tr.
Carp	..	..	..	..	4	..	..	4	tr.
Sucker	..	..	..	..	3	..	..	3	tr.
Dogfish	1	..	..	..	23	..	..	24	tr.

* Incomplete.
† Figures probably include a number of hybrids.
‡ Trace — less than 0.5 per cent.

Clear and Portage lakes. A total of 5,277 fish, caught at an average rate of 1.2 fish per hour, was reported by the census takers. In 1935, according to the Michigan general census, made by Conservation officers and representing a sampling of the fishing, the lakes in the two lower tiers of counties, which include the Waterloo Area, yielded a catch per hour of 3.1 fish in January, 3.3 in February, and 1.2 in March. The catch per hour on the lakes in the Waterloo Area in the winter of 1936 was much lower, therefore, than that in southern Michigan, as reported in the 1935 general census.

Of all fish recorded during the winter of 1936 in the Waterloo Area, 3,833, or 72.6 per cent, were black crappies. Rock bass, all taken in Portage Lake and nearly all during the month of March, were second in abundance. They constituted about 10.5 per cent of the reported winter catch for the Area. Perch, sunfish, and northern pike were each represented by over a hundred specimens. A few individuals of a number of other species were taken. In general, the fishing centered on the black crappie, and this species was fished for primarily in Clear Lake.

Concentration of winter fishing on relatively few lakes has been noted in creel census studies elsewhere in Michigan (Hazzard and Eschmeyer, 1937). The reason for such concentration may be explained by the catch, which averaged 0.1 fish per hour for all lakes except for Portage and Clear lakes, where the yield was respectively 0.8 and 1.7 fish per hour. Why some lakes should provide better winter fishing than others cannot be accounted for at present.

Fishing was not intensive during the period when the census was not taken. Snow was exceptionally deep, a condition which made access to some of the lakes difficult, and the weather was unusually cold. It is probable, therefore, that the entire catch for the Area during the winter was not over 7,500 fish, a catch of about 5.7 fish per acre for the twelve lakes.[3]

SUMMER AND FALL FISHING

Relatively detailed information is available on the summer and fall fishing on the lakes in the Area. It was estimated by the Waterloo Project that the census takers secured records of 90 per cent of the fish yield. Unless otherwise indicated, the information given below

[3] A complete census of winter fishing was conducted on the lakes during 1936–37.

is based on the records submitted and represents, therefore, about 90 per cent of the actual fishing.

Data for each lake were tabulated by weekly intervals in the complete report, but in this paper are summarized for the season. There follows a discussion of the results of the census.

Number of fishermen (Table II). — The total number of fishermen from whom reports were obtained during the season ranged from 2,141 on Portage Lake to 3 on Mud Lake. The small amount of fishing on Mud and Green lakes may be explained by the fact that in both suffocation under the ice practically eliminated the entire fish population during the preceding winter. Records of 8,325 fisherman days were obtained. If they represent 90 per cent of the fishing, the total may be estimated at 9,250, an average of approximately seven fisherman days per acre for the twelve lakes during the summer and fall.

Fishermen taking no fish (Table II). — Twenty-nine per cent of all the fishermen caught no legal-sized fish. The percentage of unsuccessful anglers varied from 3 in Doyle Lake to 81 in Waterloo Mill Pond. On the four lakes which supported over a thousand fisherman days (Clear, Mill, Portage, and Sugarloaf) the number taking no fish varied from 21 per cent on Mill Lake to 40 on Sugarloaf.

Number of legal-sized fish taken (Table II). — Records indicate a yield of 37,163 fish. The total number taken was therefore estimated at 41,292 fish, an average of about 32 per acre for the twelve lakes. The per acre catch ranged from about one per eight acres in Mud Lake to 114 per acre in Doyle Lake. The yield of the different lakes varied decidedly.

It would be interesting and useful to know what proportion of the total number of legal-sized fish occurring in the lakes these annual catches represent. Some clue to this problem may be afforded as a result of complete or nearly complete fish mortality in two lakes in the area. Mr. Gerald P. Cooper, formerly of the Institute staff, counted samples of the fish which were killed by suffocation during the winter of 1936, and from his counts calculated that the total population in Mud Lake had been 72,000 game fish averaging approximately six inches in length, and in Green Lake, 90,000 game fish averaging about seven inches. Since these counts did not include fish of the smaller sizes or the fish which died and remained in deeper water, they are probably conservative. If the

TABLE II

DATA ON THE FISHING ON TWELVE LAKES IN THE WATERLOO AREA FOR THE PERIOD JUNE 25 — NOVEMBER 30, 1936

Lake	Number of fishermen	Fishermen taking no fish		Number of legal-sized fish taken	Total hours fished	Fish per fisherman	Fish per hour	Average size of fish (inches)	Hours per fisherman day	Estimated number of fish per acre *
		Number	Percentage							
Cassidy	23	5	22	151	75.0	6.6	2.0	8.7	3.3	4.7
Cedar	452	74	16	2,795	1,293.0	6.2	2.2	7.6	2.9	55.4
Clear	1,579	592	37	4,967	4,949.8	3.1	1.0	7.7	3.1	40.3
Crooked	750	86	11	4,901	1,944.9	6.5	2.5	7.4	2.6	77.7
Doyle	163	5	3	1,024	359.5	6.3	2.8	7.4	2.2	113.8
Green	42	17	40	118	198.0	2.8	1.7	7.7	4.7	1.66
Mill	1,513	322	21	8,243	7,099.3	5.4	1.2	7.5	4.7	44.8
Mirror	27	9	33	153	46.0	5.7	3.3	7.3	1.7	42.5
Mud	3	0	0	7	13.5	2.3	0.5	6.6	4.5	0.12
Portage	2,141	695	32	9,306	9,659.9	4.3	0.9	8.2	4.5	21.5
Sugarloaf	1,590	634	40	5,211	5,579.5	3.3	0.9	8.1	3.5	28.2
Walsh	26	2	8	278	107.0	10.7	2.6	7.5	4.1	30.2
Waterloo Mill Pond (lower) †	16	13	81	9	33.5	0.6	0.4	..	2.1	0.95
Totals or averages for records available	8,325	2,454	29	37,163	31,358.9	4.5	1.2	7.8	3.8	31.6
Totals for all fishing *	9,250	2,727	..	41,292	34,843.2	.	..	..	..	..

* It is assumed in this column that the 90 per cent coverage by census was representative of all fishing. The figures used indicate, therefore, the estimated total catch per acre.

† Data represent less than 90 per cent of the fishing.

populations in Mud and Green lakes are representative, the Waterloo Area lakes probably contain an average of 1,000 game fish per acre, averaging from six to seven inches in length. At least 50 per cent of the fish counted were over six inches long, so that a conservative estimate of those available to the angler would be 500 to the acre. On the basis of this estimate, fishing in summer and fall removed less than 7 per cent of the total number of the legal-sized fish.

Hours fished (Table II). — A total of 31,358.9 fishing hours was recorded. From this it is estimated that there were about 35,000 hours of fishing, or an average of 26.6 hours per acre. The average fishing day was 3.8 hours, but it varied considerably in different lakes.

Catch per hour and per angler (Table II). — On the average, the

TABLE III

CATCH OF FISH, BY SPECIES, FROM TWELVE LAKES IN THE WATERLOO AREA, SUMMER AND FALL OF 1936

Lake	Bluegill *	Common sunfish *	Yellow perch	Large-mouthed bass †	Small-mouthed bass †	Rock bass	Black crappie	Bullhead	Northern pike	Dogfish	All others ‡	Total
Cassidy....	80	18	19	12	..	22	..	..	..	..	..	151
Cedar.....	1,985	387	150	126	85	4	9	46	..	..	3	2,795
Clear.....	3,015	335	215	374	69	328	451	147	4	1	28	4,967
Crooked....	2,770	995	601	168	100	32	..	225	5	5	..	4,901
Doyle.....	517	222	60	35	16	3	157	10	3	1	..	1,024
Green.....	..	7	84	..	..	..	..	26	..	..	1	118
Mill.....	5,798	1,284	495	143	70	42	123	218	63	7	..	8,243
Mirror.....	115	31	1	3	3	..	..	..	..	..	..	153
Mud.....	..	3	4	..	..	..	..	..	..	..	..	7
Portage....	7,661	295	269	375	50	136	240	99	165	4	12	9,306
Sugarloaf...	2,728	671	613	132	36	173	116	499	202	34	7	5,211
Walsh.....	137	37	75	6	3	..	..	20	..	..	..	278
Waterloo Mill Pond....	..	..	..	..	..	7	..	..	..	2	..	9
Totals.....	24,806	4,285	2,586	1,374	432	747	1,096	1,290	442	54	51	37,163
Percentage of total	67	12	7	4	1	2	3	3	1	tr. §	tr.	

* Figures probably include a number of hybrids.
† Identification of bass species probably not reliable.
‡ Includes 38 minnows, 3 warmouth bass, 9 gars, and 1 unknown fish.
§ Trace — less than 0.5 per cent.

fishermen caught about 4.5 fish each, at the rate of 1.2 fish per hour. The catch ranged from about one fish for two hours of fishing on Waterloo Mill Pond and Mud Lake to over three fish per hour on Mirror Lake. On the four lakes supporting the most fishing the average catch ranged from 0.9 to 1.2 fish per hour. These figures are somewhat below the average (1.8) for the two lower tiers of counties, as was revealed by the 1935 general census for Michigan.

Average size of fish caught (Tables II, IV). — The average sizes of all fish taken in the different lakes did not vary greatly, but certain species ran larger in some lakes than in others. Portage Lake, for example, produced the largest bluegills, sunfish, and perch; Cedar Lake, the largest bass; Sugarloaf, the largest rock bass, black crappies, and northern pike; and Clear Lake the largest bullheads.

TABLE IV

Average Total Length in Inches of Fish of Various Species Caught June 25 — November 30, 1936

Species omitted for lakes where fewer than 100 individuals of a species were taken.

Species	Cedar	Clear	Crooked	Mill	Portage	Sugar-loaf
Bluegill	7.2	6.9	7.0	7.2	7.7	7.1
Sunfish	6.8	6.5	6.9	6.9	7.3	6.7
Yellow perch	8.1	7.9	7.3	7.6	8.2	8.2
Large-mouthed bass	13.3	12.3	12.7	12.7	12.7	12.6
Small-mouthed bass	..	..	11.9	..	..	..
Rock bass	..	7.8	..	..	7.2	8.6
Black crappie	..	8.4	..	8.4	8.5	10.8
Bullhead	..	10.5	8.2	9.2	..	10.2
Northern pike	..	..	..	..	18.6	19.9

Catch by species (Table III). — Bluegills represented 67 per cent of all fish caught during the summer and fall, and were dominant in the catch in every lake. Sunfish, some possibly bluegills or hybrids between bluegills and sunfish, represented 12 per cent of the catch. Four of every five fish were either bluegills or sunfish. Other species taken, together with the percentages of the entire yield represented by them, were: perch, 7; large-mouthed bass, 4; small-mouthed bass, 1; rock bass, 2; black crappies, most prominent in the winter catch, 3; bullheads, 3; northern pike, 1. Fish taken in relatively insignificant numbers include dogfish, minnows, warmouth bass, and gars.

Residence of the anglers. — Only 6 per cent of the fishermen were nonresidents. Of these 514 fishermen, 467 (91 per cent) were from Ohio. Eleven other states were represented, as follows: Illinois, 18; Indiana, 6; Florida, 3; Kentucky, 2; New Hampshire, 1; New York, 2; Pennsylvania, 5; Virginia, 2; Iowa, 2; California, 1; and Missouri, 1. Four fishermen were from Canada. The percentage of nonresidents was very much lower than has been found for certain other waters in northern Michigan.

Of the 7,440 residents 93 per cent were from three counties (Jackson, 43 per cent; Wayne, 29; and Washtenaw, 21). Twenty-three other counties were represented, all except two of them by

TABLE V

DATA ON THE USE AND EFFECTIVENESS OF THE SEVERAL METHODS OF FISHING

Method	Hours recorded		Fish taken		Fish taken per hour	Average length of fish (inches)
	Number	Percentage	Number	Percentage		
Still-fishing	22,351.44	85	29,618	94	1.3	7.5
Trolling	1,161.75	4	828	2	0.7	8.9
Casting	2,886.25	11	1,109	4	0.4	12.0

fewer than twenty fishermen. The lakes mostly attract fishermen living within a radius of fifty miles. In contrast, over half the fishing on Fife Lake, Grand Traverse and Kalkaska counties, was by anglers living two hundred miles or more away (Eschmeyer, 1937).

Woman anglers. — Sixteen per cent (1,367) of the anglers were women, of whom an even hundred were nonresidents.

Fishing methods (Table V). — Still-fishing, which was employed by 85 per cent of the anglers, yielded 94 per cent of the fish caught. Trolling made up 4 per cent of the fishing and accounted for 2 per cent of the catch. Eleven per cent was by casting, which produced 4 per cent of the fish taken. Still-fishing yielded, in general, the smallest fish and casting the largest. This relatively close correlation between size of fish and number of fish per hour taken by any one method is in accord with findings on other Michigan lakes (Eschmeyer, 1936, 1937).

Data are available for the effectiveness of each method in taking fish of each of the species most commonly caught in the several lakes, but this information is too copious to be included. It may be stated briefly that still-fishing was decidedly the most used and the most effective method in catching bluegills and sunfish. Trolling was the most effective, but the least used, in catching large-mouthed bass.

Baits used (Table VI). — Worms were the most popular bait. They were used in 75 per cent of the fishing and accounted for 83 per cent of the fish. Minnows were employed for 10 per cent of the fishing and insects for 6 per cent. These three natural baits yielded 97 per cent of all the fish taken. The remaining 3 per cent were

TABLE VI

USE AND EFFECTIVENESS OF VARIOUS KINDS OF BAIT

Bait used	Hours each bait was used		Fish taken by each bait		Fish taken per hour	Average size of all fish (inches)
	Number	Percentage	Number	Percentage		
Natural						
Worms	17,711.9	75	23,581	83	1.3	7.3
Insects	1,386.5	6	2,393	8	1.7	7.7
Minnows	2,406.5	10	1,686	6	0.7	10.1
Artificial						
Spinners	148.5	1	71	0.5	0.5	13.2
Plugs	1,700.5	7	615	2	0.4	12.0
Artificial flies	116.0	1	83	0.5	0.7	9.0

caught on artificial lures (spinners, plugs, and flies). Spinners and plugs yielded, on the average, the largest fish, also the fewest fish per hour.

Natural bait was decidedly the best for taking bluegills. Insects were first in effectiveness, worms second. Sunfish were caught most readily with worms; their next favorite food was insects. Of the artificial lures used for large-mouthed bass spinners ranked first, plugs second. Almost all the perch, which preferred minnows to worms, were taken by natural bait. These preferences were generally the same for each lake.

DISCUSSION AND CONCLUSIONS

(1) The average yield on the lakes of the Waterloo Area for the year 1936 is estimated at 37.7 fish per acre. This is believed to represent less than 8 per cent of the fish available to the fisherman. If this assumption is correct, it is evident that these lakes are not intensively fished at present and could support a much greater fishing pressure without any danger of depletion.

(2) A considerable variation in the yield of fish per acre is apparent in the different lakes. As a general rule, the larger lakes attracted the most anglers, but the intensity of fishing (in terms of fisherman hours per acre), catch per hour, and number of fish removed per acre were greater in the smaller lakes. The reasons

for such variation may be revealed when a study of the survey data is completed. This interpretation should make it possible, at least in some instances, to suggest for the poorer lakes environmental improvements which will increase their yield.

(3) The results of the census indicate that ice fishing has little, if any, harmful effect upon the yield during summer and fall. This conclusion is in accordance with the authors' findings (1937) on several lakes in the northern part of the state. The number of fish removed by winter fishing is only a fraction of that caught during the rest of the year; in Waterloo lakes it consists principally of species which are not of greatest importance in summer fishing (crappie, rock bass, perch, pike and sunfish). Furthermore, these species, with the probable exception of the sunfish, are highly predaceous and are known to consume large numbers of young bluegills, so that winter fishing as practiced on such lakes may actually benefit open-water fishing by reducing predation of the bluegills.

(4) Continuation of fish-yield studies in the Waterloo Project by means of creel census is highly desirable in order to establish the normal yield for these waters, to note annual fluctuation in the catch, to ascertain changes in fishing pressure, and to determine the effectiveness of stocking and environmental improvements.

University of Michigan

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FEEDING HABITS OF BROOK TROUT FRY IN NATURAL WATERS*

JUSTIN W. LEONARD

THE purpose of this brief note is to place on record certain findings in regard to the feeding habits of fry of brook trout (*Salvelinus fontinalis*) which are at variance with other published observations.

On March 24, 1936, Mr. D. S. Shetter, of the Institute for Fisheries Research, and I made a census of brook trout fry in the North Branch of the Au Sable River near Lovells, Crawford County, Michigan. The section of stream selected was one in which we had observed heavy concentrations of spawning brook trout during the two preceding spawning seasons. Of the fish secured at this time a series was preserved for study. Stomach analyses were conducted on fifty individuals, ranging in standard length from 17 to 22 mm., average 19.18 mm.

A survey of the literature indicates that relatively few studies of trout feeding habits have included very young fish. Among these are the investigations of Clemens (1928), Ricker (1930), and White (1930). The relation of my findings to those of Clemens is somewhat obscured by his method of recording, since he considered together all fish 2 inches or less in length. Ricker's studies show that 28 per cent of the diet of brook trout 0.8–1.0 inch in length was made up of Chironomidae, the remainder being largely ostracods and copepods; in fry 1.0–1.5 inches in length the diet had increased to 73 per cent Chironomidae, and there were only small amounts of the other two groups mentioned. White, working on fry obtained from a small stream on Prince Edward Island, found that chironomid larvae made up almost 70 per cent of the total stomach contents, with small amounts of copepods, black-fly larvae, mayfly nymphs, and oligochaete worms forming the remainder.

* Contribution from the Institute for Fisheries Research of the Michigan Department of Conservation and the University of Michigan.

The results of the present analysis may be tabulated as follows:

	Percentage
CRUSTACEA	
Copepoda	3.4
INSECTA	
Collembola	3.8
Ephemeroptera	
Baetidae (nymph)	0.7
Odonata	
Gomphidae (nymph)	0.2
Plecoptera	
Capniidae (nymph)	1.5
Trichoptera	
Limnephilidae (larvae)	0.1
Diptera	
Chironomidae (larvae)	11.4
Chironomidae (pupae)	78.6
Undetermined (2 larvae)	0.3
Total	100.0

Thus it may be seen that 90 per cent of the food consumed in the North Branch was composed of midge larvae and pupae. It is interesting to observe that the pupae bulked approximately seven times as large as the larvae, although bottom samples taken not far from the site of the trout collections had contained from forty to three hundred times as many larvae as pupae. One species of midge, apparently an *Orthocladius*, made up most of the volume. Three examples of another species of *Orthocladius* and one of *Tanytarsus* were encountered among the pupae.

The high percentage of chironomids in the stomachs is quite striking; it indicates that they may become preferred items of diet for trout fry less than one inch in length.

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SOME NEW MUTATIONS IN *DROSOPHILA*

A. FRANKLIN SHULL

MUTATIONS in *Drosophila melanogaster* are still worth putting on record if they have peculiarities which merit investigation or if they promise to be useful tools in other studies. One of the mutations that have arisen in the experiments of Miss Jean Brierley appears to meet both of these requirements. This mutation involves a spread of the wings at an angle to each other of as much as 150° in some individuals. Occasionally the membranes of the wings are separated and the space between is filled with a liquid, as in balloon. The inflated region collapses later, and only an undulatory area of the dry wing indicates where the expansion was; or the wing may be wholly crumpled if it was swollen throughout. These characters, the usual spread of the wings and their occasional inflation, suggest the name "Puffdivergent," but the abbreviation Pufdi has long been in use in the laboratory, and it is proposed that this short name be retained. The suggested symbol is *Pfd.*

All efforts to obtain a true-breeding stock of Pufdi have failed. Pufdi parents, mated singly, have yielded always some wild-type as well as Pufdi offspring, suggesting that the Pufdi individuals are always heterozygous. Matings of Pufdi to wild have always yielded more wild-type than Pufdi offspring, again an indication of heterozygosis in all the Pufdi used. Certain results mentioned later confirm this suggestion; hence it is concluded that Pufdi is lethal in the homozygous state.

Crosses of Pufdi with several mutations independent of one another showed linkage between Pufdi and brown eye, indicating that the new mutation is in chromosome 2. These preliminary tests also showed roughly 20 to 30 per cent of crossing over between brown and Pufdi. Since brown is near the right end of the chromosome and there is not a distance of twenty to thirty units to its right, Pufdi must be to the left of brown, and in the general region of loci 70 to 80. Brief tests with four-jointed made it probable that

the locus was nearer 70 than 80, so that Lobe^2 (locus 72) was used for the more extensive experiments designed to locate the new gene.

It was early discovered that genotypically Pufdi flies do not always show the spread of the wings, as is more particularly mentioned later. No other constant modification resulting from the gene has been found, though a search was made. In the crossover tests with Lobe^2, therefore, only those offspring which were undoubtedly Pufdi were used, and the percentage of recombination among these flies was determined. Unless Lobe^2 has some effect on the expression of Pufdi, this procedure should not lead to any incorrect conclusions. Pufdi was mated to Lobe^2, and their Pufdi Lobe^2 female offspring were crossed to wild males. The certainly Pufdi offspring from the latter cross were examined for the character of the eyes, with the following results: 2141 Pufdi, 26 Pufdi Lobe^2. This indicates 1.2 per cent of crossing over.

To determine on which side of Lobe^2 Pufdi is located, a stock of Pufdi four-jointed (*Pfd fj/fj*) was made up and crossed with Lobe^2. The Pufdi/Lobe^2 female offspring (*Pfd fj/L*^{2}) were mated to four-jointed males, and their occasional Pufdi Lobe^2 offspring were examined for four-jointed. When the first few of these Pufdi Lobe^2 flies were all found to have normal tarsi, it was concluded that Pufdi is to the left of Lobe^2. Were it to the right of Lobe^2, the Pufdi Lobe^2 (not four-jointed) offspring would have to result from double crossovers in a very short distance. Since the locus of Lobe^2 is 72, that of Pufdi should therefore be about 70.8.

This close proximity of Pufdi to Lobe^2 makes it easier to maintain a stock of Pufdi in combination with Lobe^2 (*Pfd L*^{2}) than by itself (*Pfd*/+). Pufdi and Lobe^2 are both lethal in the homozygous state, and there is little crossing over between them. Consequently they make, together, a fairly good balanced stock. The value of the combination with Lobe^2 is the greater because Pufdi appears to come to expression better with Lobe^2 than without it. That is, among the offspring of Pufdi/Lobe^2 parents there are almost no Lobe^2 flies which lack spread wings.

This presumable effect of Lobe^2 on the expression of Pufdi raises the question whether the linkage relation of Pufdi with Lobe^2 has been correctly determined. As previously stated, in the linkage tests only those flies which were certainly Pufdi were examined with respect to their eyes. If every genotypically Pufdi Lobe^2 fly showed

its Pufdi character, while some of the genotypically Pufdi (*Pfd*/+) flies failed to show the wing mutation, the crossover percentage as determined would be too high. It may therefore prove later that the locus of Pufdi is nearer 70.9, or even 71.

A defect of Pufdi as a tool in research is its great variability under ordinary conditions. At temperatures of 24° or 25° the wings may spread as little as 20° (as determined from the rather straight portions of the front margin) or as much as 150°. The lesser angles are not distinguishable from those in wild-type flies. At lower temperatures (19°) the difficulty is still greater. Fortunately, higher temperatures accentuate the wing spread, and at 28°–29° nearly all genotypically Pufdi flies have distinctly spread wings. To determine which flies are genotypically Pufdi, virgin wild females are mated with Pufdi/Lobe^2 males, and their not-Lobe^2 offspring are regarded as Pufdi whether their wings are spread or not. The effect of temperature on Pufdi is being used in other studies, and a search for additional environmental ways of modifying the character is in progress.

Some other mutations which have arisen in our experiments are of interest chiefly as indicating the mutability of the wild stock which was collected in Ann Arbor, and the continued recurrence of mutations when these happen to be old ones. Singed has appeared, and has the characteristic of the original singed (*sn*, not *sn*^{3}) causing sterility in homozygous females. An obliquely shortened wing somewhat resembling truncate, but of very poor expression in males, was found to be in chromosome 2, and then lost before a more exact determination of its locus could be made.

A glazed condition of the eye was first found in a stock in which brown and scarlet were combined, and the glazed eye was white. Scarlet has been eliminated, and the glazed eyes are now brown. The character appears only in males. Though these glazed brown males have been repeatedly crossed to wild, and the new mutation extracted out of F_2, the glazing appears only with brown and only in some of the males, and all the browns appear now to be glazed. The explanation of these peculiarities is unknown.

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THE AGE AND GROWTH OF THE LAKE ERIE SHEEPSHEAD, *APLODINOTUS GRUNNIENS* RAFINESQUE *

JOHN VAN OOSTEN

I. INTRODUCTION

THE sheepshead or fresh-water drum, sometimes called the "gray bass" or "white perch" in the Great Lakes area, is generally distributed throughout the Great Lakes Basin and the Mississippi Valley between the Alleghenies and the western plains, ranging from Lake Champlain to the Red River of the North (Winnipeg), south to Texas and Georgia. It has been found also in Lake Abitibi, where it reaches a weight of at least 14 pounds, but has not been reported from any other northern lake in Ontario. It occurs in greatest numbers in the larger rivers and lakes and seldom enters small streams. The young sheepshead feeds almost entirely on crustaceans and insects. The adult subsists largely on mollusks, with an occasional fish or crayfish included in its diet. The sheepshead is primarily a bottom-dwelling form. Its flesh is tough and coarse, especially that of the adults, and the fish is, therefore, not highly prized on the market. Individuals have been known to reach a length of 4 feet and a weight of 60 pounds, although the average size of the Great Lakes fish on the market today is about 1½ pounds. In Lake Erie the sheepshead spawns in May and June.

The sheepshead fishery of the United States is centered in the Mississippi River and its tributaries and in the western half of Lake Erie. In 1931 the Mississippi River system produced 3,905,000 pounds of sheepshead, valued at $143,000, and the Great Lakes produced 1,633,000 pounds, valued at $42,000. In 1934 the Great Lakes yielded 2,232,000 pounds of sheepshead, valued at $38,000, of which production 2,218,000 pounds, or 99.4 per cent, were taken

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from Lake Erie and 14,000 pounds from the Michigan waters of Lakes Huron and Michigan. During the past ten years approximately 99 per cent of the annual United States catch of Great Lakes sheepshead was produced on Lake Erie. Canada produces only a small quantity of sheepshead (separate statistics not published) on Lakes Erie and Huron. Imports into the United States are probably less than 2 per cent of domestic production, while no sheepshead are exported. In 1934 about 74 per cent of the Great Lakes sheepshead (United States catch) were taken in trap nets, 19 per cent in seines, 5 per cent in fyke nets, and the remaining 2 per cent in pound nets, gill nets, and trammel nets. From 85 to 90 per cent of the annual United States yield on the Great Lakes is taken during the months of April, May, and June. Practically the entire Great Lakes catch is sold fresh without being dressed, the fish bringing an average of about 2 or 3 cents per pound to the fishermen.

TABLE I

Average Annual United States Catch of Sheepshead on the Great Lakes for Various Periods of Years, Usually Five Years, from 1899 to 1934 Inclusive

Years	*Average catch, in pounds*
1899, 1903, 1908, 1913	944,795
1914–19	2,504,149
1920–24	2,031,838
1925–29	2,798,134
1930–34	2,391,320

Very few sheepshead were marketed on the Great Lakes before the late nineties, although they were plentiful in Lake Erie, where they were looked upon as trash. Not until about 1914 were sheepshead considered worth bringing ashore to be sold. Production of this species did not start on Lakes Huron and Michigan until 1919. The available annual statistics covering twenty-five years show that the production of sheepshead is being maintained on the Great Lakes, although the species is not propagated or given any protection by law except a size limit of 11 inches in Ohio and 12 inches in Ontario. Table I gives the average annual United States catch of sheepshead on the Great Lakes for various periods of years, usually five years, from 1899 to 1934 inclusive.

Virtually nothing has been published on the different phases of

the life history of the sheepshead, such as spawning, migration (Thompson tagged 214 sheepshead in Illinois rivers and recovered tags from 2 fish), age, and growth.

II. MATERIALS AND METHODS

The sheepshead on which the present study is based were taken from Lake Erie by means of trap nets and gill nets. The data on length–weight relationship were based on 2,183 fish and those on age and growth on 784 specimens, all of which were taken at Vermilion, Ohio, and Sandusky, Ohio, during the period August 17—November 21, 1927. The 1,570 sheepshead used for a study of the relationship of total to standard length were taken at several ports in 1927 and 1928. All measurements were obtained by means of a steel tape and from fresh fish in the field. Length measurements were recorded in millimeters, weights in ounces. Age determinations and growth computations based on scales were made by Dr. C. W. Greene, formerly a member of the Great Lakes staff of the United States Bureau of Fisheries, but many of his readings were verified by me. Ages are expressed by roman numerals and indicate the number of annuli found on the scales. Measurements of the projected images of the scales were made along the anterior radius. Computations of growth were made on the assumption that the body-scale ratio is constant at all times beyond the formation of the first annulus.

Because of the fact that the legal-sized fish were marketed in the round, very few of the larger specimens were sexed. Many of the smaller fish were sexed and the stage of maturity was noted, but it was seldom possible to determine the sex of these in the field. The various types of data, therefore, could not be studied separately for the sexes. All sexed fish of age groups 0 and I were found to be immature.

Although the 1927 specimens were taken on various dates between August 17 and November 21 by two types of gear and at two localities, it was found by detailed comparisons that the differences in the actual and in the calculated lengths due to these three factors were so slight or so inconsistent that they could be ignored. Each age group, therefore, was considered a homogeneous unit. I am greatly indebted to Doctors H. J. Deason and Ralph Hile for valuable assistance rendered in the preparation of the tables.

III. AGE COMPOSITION AND LENGTH FREQUENCIES

In Table II the sheepshead have been divided into age groups and according to the year class to which they belong, with the individuals of each age group arranged by their standard length. The number of individuals in each age group and the percentage of that number in the entire collection are shown at the bottom of the table. The column at the extreme right gives the number of fish of each size group. All age groups up to VIII inclusive were represented in the samples. However, two older specimens were collected — one, in its thirteenth year, measured 412 millimeters in length (about 19.7 inches total length) and weighed 3 pounds 15 ounces; the other, in at least its seventeenth year, measured 576 millimeters in length (about 27.2 inches total length) and weighed 7 pounds 14 ounces (collected in 1928). Age group I (year class 1926) predominated in the catch, comprising 56.2 per cent of the total number aged. It is of interest to report here that the 1926 year class was also found to dominate for several years the Lake Erie catch of yellow perch, yellow pike-perch, blue pike-perch, and sauger. It appears, then, that 1926 was an exceptionally favorable year for the survival of the spring-spawning species of fish. In 1927 the fishermen referred repeatedly to the unusual abundance of small sheepshead and yellow perch in the lake. The relative paucity of the older sheepshead in the fall samples is due in part to the fact that before and after the spring run these fish occur only as stragglers in the fishermen's nets. From 85 to 90 per cent of the annual commercial yield of sheepshead is taken from the latter part of April to the middle of June, when they apparently have schooled for spawning. At other times of the year the larger sheepshead appear to roam alone or in very small groups. It is possible that the change from a gregarious habit to a solitary existence is associated with the change from a diet of crustacea and insects to one of mollusks, which must be hunted by each individual fish on the bottom of the lake. The length frequencies show distinct modes at 105 and at 170 millimeters only (the approximate average length of age groups 0 and I respectively). The smallest specimen which was aged measured 88 millimeters in length (4.5 inches total length), the largest, recorded above, measured 576 millimeters in length (not included in tables).

TABLE II

Frequency Distribution of the Lake Erie Sheepshead according to Standard Length in Mm., Age Group (Roman Figures), and Year Class (Calendar Years), with Sexes Combined

Standard length, in mm.	Age group									
	0	I	II	III	IV	V	VI	VII	VIII	0–VIII
	Year class									
	1927	1926	1925	1924	1923	1922	1921	1920	1919	1919-27
80–89	5	...	...	..	..	..	..	..	..	5
90–99	15	...	...	..	..	..	..	..	..	15
100–109	39	...	...	..	..	..	..	..	..	39
110–119	10	...	...	..	..	..	..	..	..	10
120–129	3	...	...	..	..	..	..	..	..	3
130–139	..	6	...	..	..	..	..	..	..	6
140–149	..	19	...	..	..	..	..	..	..	19
150–159	..	60	...	..	..	..	..	..	..	60
160–169	..	120	1	..	..	..	..	..	..	121
170–179	..	122	1	..	..	..	..	..	..	123
180–189	..	87	7	..	..	..	..	..	..	94
190–199	..	21	9	..	..	..	..	..	..	30
200–209	..	6	25	1	..	..	..	..	..	32
210–219	..	...	31	2	..	..	..	..	..	33
220–229	..	...	17	4	..	..	..	..	..	21
230–239	..	...	10	9	..	..	..	..	..	19
240–249	..	...	1	6	1	2	..	..	..	10
250–259	..	...	...	2	3	3	..	..	..	8
260–269	..	...	...	2	2	..	..	..	..	4
270–279	..	...	...	1	3	5	..	..	..	9
280–289	..	...	...	..	4	6	1	..	..	11
290–299	..	...	...	..	1	5	3	1	..	10
300–309	..	...	...	..	..	4	3	1	1	9
310–319	..	...	...	..	..	4	4	4	1	13
320–329	..	...	...	..	..	1	3	3	2	9
330–339	..	...	...	..	..	2	5	4	2	13
340–349	..	...	...	..	..	..	8	4	1	13
350–359	..	...	...	..	..	1	3	3	4	11
360–369	..	...	...	..	..	..	2	3	6	11
370–379	..	...	...	..	..	..	2	1	11	14
380–389	..	...	...	..	..	..	2	..	2	4
390–399	..	...	...	..	..	..	..	..	2	2
400–409	..	...	...	..	..	..	..	..	2	2
410–419	..	...	...	..	..	..	..	..	..	...
420–429	..	...	...	..	..	..	..	..	..	...
430–439	..	...	...	..	..	..	..	..	1	1
Number	72	441	102	27	14	33	36	24	35	784
Percentage	9.2	56.2	13.0	3.4	1.8	4.2	4.6	3.1	4.5	...

TABLE III

AVERAGE LENGTH AND WEIGHT, INCREMENT IN WEIGHT, AND AVERAGE CALCULATED LENGTHS FOR EACH YEAR OF LIFE OF EACH YEAR CLASS AND AGE GROUP OF THE LAKE ERIE SHEEPSHEAD, WITH SEXES COMBINED

The grand averages of calculated lengths and increments in length are given at the bottom of the table. Total lengths were computed by means of the ratios of Table VI.

Year class	Age group	Number of specimens	Average standard length, in mm.	Average total length, in inches	Average weight, in ounces	Increment in weight	Calculated standard length, in mm., at end of year of life							
							1	2	3	4	5	6	7	8
1927	0	72	103	5.3	0.83 (30) *	0.83	...	...	...	...	...	...	...	...
1926	I	441	171	8.6	3.68 (392)	2.85	94	...	...	...	...	...	...	...
1925	II	102	211	10.4	6.98 (78)	3.30	102	170	...	...	...	...	...	...
1924	III	27	238	11.8	10.55 (25)	3.57	76	158	208	...	...	...	...	...
1923	IV	14	269	13.2	15.38	4.83	86	146	205	238	...	...	...	...
1922	V	33	292	14.3	20.05 (32)	4.67	93	155	192	242	269	...	...	...
1921	VI	36	332	16.1	30.19 (34)	10.14	102	168	211	244	281	313	...	...
1920	VII	24	336	16.3	32.28	2.09	86	154	206	236	263	296	320	...
1919	VIII	35	365	17.6	44.22 (31)	11.94	95	157	213	247	272	298	329	349
Grand averages calculated length, I-VIII							94	162	206	242	272	303	325	349
Grand averages annual length increments							94	68	44	36	30	31	22	24
Number of specimens							712	271	169	142	128	95	59	35

* Number of specimens used to obtain average, when less than the total number, is indicated in parentheses.

IV. GROWTH IN LENGTH AND WEIGHT

Table III shows for sexes combined the average length and weight and the computed length for each year of life of the sheepshead of each age group, and the increments in weight and in computed lengths as determined from the various averages. The curves

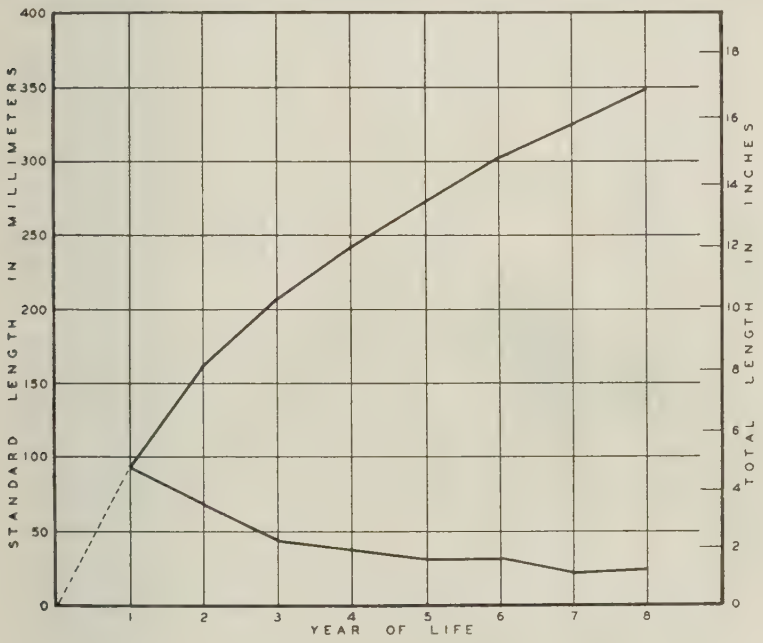

FIG. 1. Growth curves of the Lake Erie sheepshead

Upper curve — average calculated length at end of each year of life. Lower curve — average calculated increment in length for each year of life. Curves based on grand averages of Table III. The scale of total lengths at right does not apply to the increment curve

of Figure 1 are based on the grand averages of the computed lengths and the annual increments in length given at the bottom of the table; the curve of Figure 2 is based on the average weight of the various age groups.

The computed lengths indicate considerable variation in the growth of the different year classes. For example, the 1924 year

class reached a length of only 76 millimeters in the first year of life, whereas the 1921 and 1925 year classes attained a length of 102 millimeters. The 1920 and 1923 year classes grew 86 millimeters and the 1919, 1922, and 1926 year classes reached approximately 94 millimeters in length during the first year. Differences in rates of growth occurred also in the other years of life. Figure 1 shows the

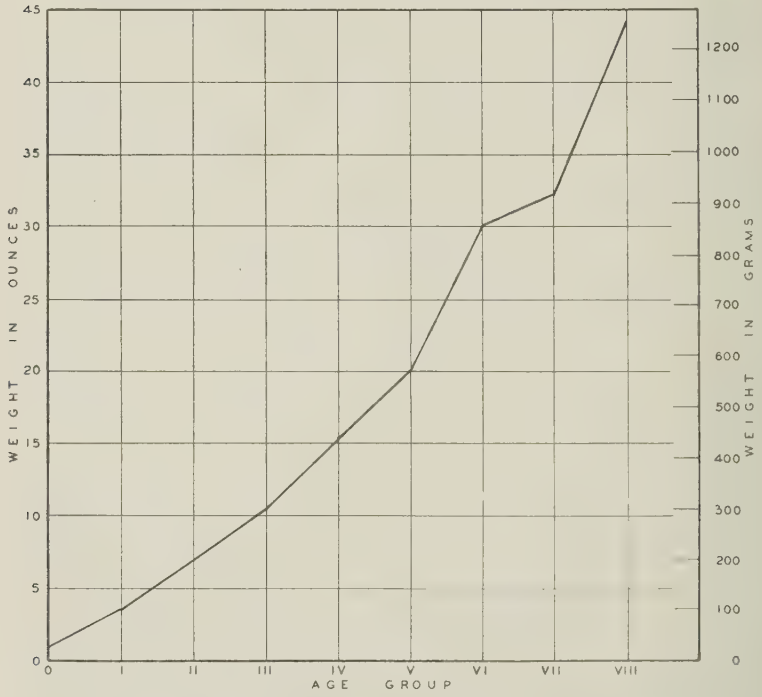

Fig. 2. Average weight of age groups 0–VIII of the Lake Erie sheepshead (data from Table III)

typical growth curve of the sheepshead. The increment curve drops rapidly in the second and third years of life and thereafter falls very gradually or maintains its level. If the length at the end of the eighth year of life (349 millimeters) is taken as 100 per cent, then it may be stated that 27 per cent of the total growth in length is completed at the end of the first year of life, 46 per cent at the end

of the second, 59 per cent at the end of the third, 69 per cent at the end of the fourth, 78 per cent at the end of the fifth, 87 per cent at the end of the sixth, and 93 per cent at the end of the seventh.

The curve of Figure 2, based on the average weights of the age groups, shows a slight irregularity which cannot be explained at the present time. The average weight of age group VI seems to be too high in comparison with that of age groups V and VII. If the curve were smoothed the average of the VI-year fish would be about 26 ounces instead of 30. The ages of these fish were checked twice and found to be accurate. There was no selection by gear since all but two of the specimens of age group VI were taken in small-meshed trap nets set off Sandusky, Ohio. If the sexes grow at different rates, it is possible that a change in sex ratios may account for the inconsistency. The increments of the curve based on average weights show a trend exactly opposite that of the increments of the curve based on average lengths (Fig. 1). The data of Figure 2 and Table III indicate that the annual increment of growth in weight increases progressively during at least the first nine years of life. The fact that the curve and the increments of weight continue to rise rapidly in the ninth year suggests that sheepshead of this age with an average weight of $2\frac{3}{4}$ pounds are still in the midst of a fast-growing period of life so far as weight is concerned. If the average weight of the fish in their ninth year of life (age group VIII, 44.22 ounces) is taken as 100 per cent, then it may be determined that 2 per cent of the total growth in weight is completed in the first year of life, 8 per cent in the second, 16 per cent in the third, 24 per cent in the fourth, 35 per cent in the fifth, 45 per cent in the sixth, 68 per cent in the seventh, and 73 per cent in the eighth. Since the oldest fish were still growing rapidly in weight, these percentages would no doubt be less for each year if fish near the end of the maximum life span were available as a standard for comparison.

It may be observed from the percentages of length and weight that, whereas 46 per cent of the total length is reached at the end of the second year, about six years are required to reach this percentage of total weight. Only 2 per cent of the total growth in weight is completed in the first year as against 27 per cent of the total length. In comparison with length the percentage rate of increase in weight is small during the first three or four years of life, but thereafter both rates seem to be approximately the same (compare

for length and weight the differences between the percentages of growth completed in the various years of life).

The data on growth indicate that the sheepshead are being removed from the lake by commercial fishing at a period in their life when they are growing most rapidly. However, since the flesh of this species is not of a high quality and the market for it is therefore limited, and since the flesh becomes less palatable with increased size, and, furthermore, since there is no evidence that the sheepshead is being depleted in Lake Erie, it would not be desirable at the present time to increase the size limit of the species to the length at which the rate of increase in weight diminishes.

V. GROWTH COMPENSATION

To ascertain whether a compensation in growth occurs in the sheepshead, the fish of age group II were divided into three size groups according to the computed lengths at the end of the first year of life (Table IV). The average length of the fish of each size group was then determined for each year of life. From these total lengths the average annual increments were derived. It may be seen from the table that the big yearlings were, on the whole, the big fish in all succeeding years, but that the maximum differences between the lengths of the three size groups diminished progressively

TABLE IV

GROWTH COMPENSATION. AVERAGE CALCULATED STANDARD LENGTH AND AVERAGE INCREMENT IN LENGTH FOR EACH YEAR OF LIFE OF THREE SIZE GROUPS OF THE LAKE ERIE SHEEPSHEAD OF AGE GROUP II

Size groups are based on the computed lengths at the end of the first year of life.

Size group, in mm.	Number of specimens	Average calculated length in year		Length at capture	Average increment during year		
		1	2		1	2	3*
Under 99	33	89	163	205	89	74	42
99 to 106	39	103	170	212	103	67	42
107 and over	30	115	177	215	115	62	38
Maximum difference		26	14	10	...	..	..

* An incompleted year.

each year, so that the fish became more uniform in size at each successive age. Or, as may be seen from the increments, the smaller yearlings were the faster-growing fish and the larger yearlings the slower. It appears, then, that the "law of growth compensation" applies to the Lake Erie sheepshead.

VI. LENGTH–WEIGHT RELATIONSHIP AND COEFFICIENT OF CONDITION

The curve of Figure 3, based on the data of Table V, has been drawn to show the relationship between the length and the weight

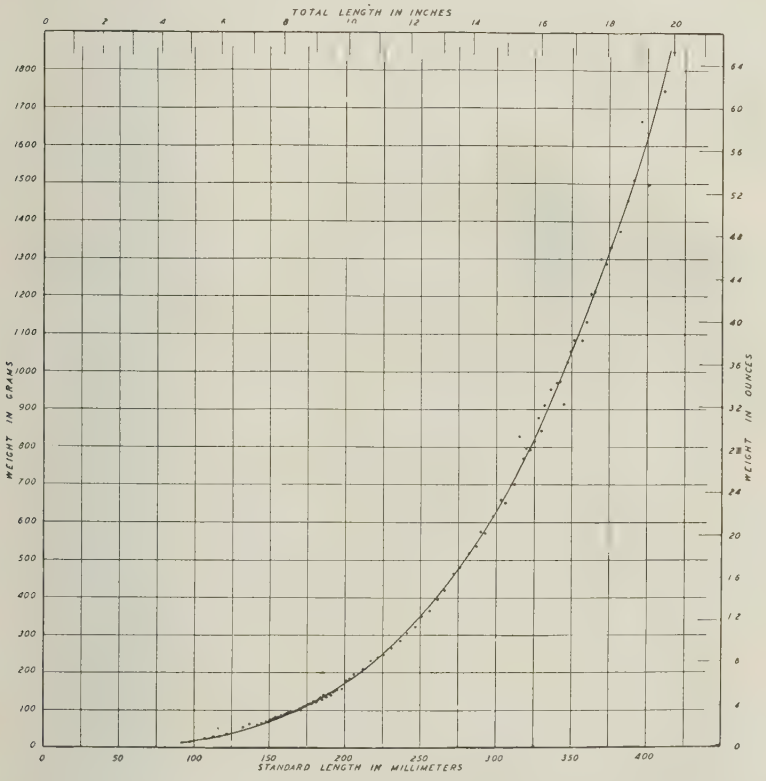

Fig. 3. Length–weight relationship of the Lake Erie sheepshead (data from Table V)

TABLE V

LENGTH–WEIGHT RELATIONSHIP OF 2,183 LAKE ERIE SHEEPSHEAD, WITH SEXES COMBINED

Standard length, in mm.	Weight, in grams	Number of specimens	Standard length, in mm.	Weight, in grams	Number of specimens	Standard length, in mm.	Weight, in grams	Number of specimens
92	12	4	176	116	31	287	537	10
98	14	2	177	117	43	290	576	11
103	19	8	178	117	66	293	571	11
107	21	5	179	122	23	298	617	22
113	28	5	180	123	55	303	659	8
117	28	6	181	122	23	306	652	9
122	35	2	182	125	21	312	701	15
133	53	2	183	131	34	315	829	13
137	62	10	184	134	16	318	770	18
142	60	15	185	128	28	320	797	14
145	65	14	186	140	11	322	794	14
148	69	17	187	136	14	325	816	18
150	70	18	188	135	26	328	878	14
151	74	13	189	143	16	330	844	14
152	73	17	190	144	16	332	911	17
153	76	32	191	139	6	336	953	20
154	81	22	192	149	11	340	971	20
155	78	21	193	150	14	342	975	19
156	82	29	195	154	9	345	915	14
157	81	38	198	156	10	347	1026	17
158	85	31	201	179	10	350	1054	18
159	83	22	203	184	13	352	1085	22
160	87	43	206	195	16	357	1084	17
161	89	30	212	209	16	360	1133	17
162	92	36	217	231	17	363	1206	16
163	93	53	222	240	17	366	1212	19
164	96	38	226	247	14	370	1300	15
165	94	55	231	266	10	373	1287	15
166	95	30	237	285	15	376	1331	19
167	96	40	242	306	9	382	1374	13
168	99	63	247	322	7	387	1455	10
169	100	19	251	350	5	391	1510	4
170	104	61	256	365	10	396	1666	3
171	100	30	262	394	9	401	1498	5
172	106	37	266	418	6	411	1747	6
173	110	52	272	464	16	417	1850	1
174	110	30	276	480	11	432	2240	1
175	112	46	282	518	14	...	...	..

TABLE VI

TOTAL LENGTH-STANDARD LENGTH RATIOS $\left(\frac{\text{T.L.}}{\text{S.L.}}\right)$ OF 1,570 LAKE ERIE SHEEPSHEAD ARRANGED BY SIZE GROUPS OF 25-MM. INTERVALS, STANDARD LENGTH

Standard length interval, in mm.	$\frac{\text{T.L.}}{\text{S.L.}}$	*Number of specimens*
75–99	1.302	5
100–124	....	0
125–149	1.276	44
150–174	1.274	688
175–199	1.265	398
200–224	1.258	42
225–249	1.255	35
250–274	1.246	27
275–299	1.250	49
300–324	1.242	79
325–349	1.233	85
350–374	1.226	81
375–399	1.222	27
400–424	1.217	10

of sheepshead of different sizes. It has been so plotted that standard lengths in millimeters may be converted readily to total lengths in inches and vice versa, and weight in grams to weight in ounces and vice versa. The conversion of standard to total lengths and its reverse was accomplished by means of the total length standard length ratios $\left(\frac{\text{T.L.}}{\text{S.L.}}\right)$ determined empirically for 1,570 fish that ranged from 84 to 417 millimeters, standard length (Table VI). In Table VII total lengths in inches and millimeters have been converted to standard lengths in millimeters by employing the ratios shown in the last column. The curve of Figure 3 illustrates very well the fact that the weight of the sheepshead increases proportionately more rapidly than the length — there is a sharp rise in the curve with increase in fish-length.

The $\frac{\text{T.L.}}{\text{S.L.}}$ ratios of Table VI are of interest in that they show a progressive decrease with increase in the length of the fish, that is, the tail of the sheepshead becomes relatively shorter with growth. This conclusion appears to be in contrast to the results found for several other Great Lakes species of fish, such as the Lake Superior

TABLE VII

CONVERSION OF TOTAL LENGTHS (T.L.) IN INCHES AND MM. (ROUND NUMBERS) OF THE LAKE ERIE SHEEPSHEAD TO STANDARD LENGTHS (S.L.) IN MM., BY EMPLOYING THE $\frac{\text{T.L.}}{\text{S.L.}}$ RATIOS SHOWN

Total length, in inches	Total length, in mm.	Standard length, in mm.	$\frac{\text{T.L.}}{\text{S.L.}}$
1	25	20	1.302 *
2	51	39	1.302 *
3	76	58	1.302 *
4	102	78	1.302 *
5	127	98	1.302
6	152	118	1.289 †
7	178	139	1.276
8	203	160	1.274
9	229	181	1.265
10	254	202	1.257
11	279	222	1.259
12	305	243	1.255
13	330	265	1.246
14	356	284	1.250
15	381	307	1.242
16	406	330	1.233
17	432	352	1.228
18	457	374	1.223
19	483	395	1.222
20	508	417	1.217

* The smallest fish available was 84 mm. standard length.
† Interpolated.

longjaw and the three species of pike-perches from Lake Erie, for all sizes of which a single conversion factor can be employed.

As a part of the study of the length–weight relationship of the sheepshead, the value of the coefficient of condition, K, was determined for individual fish by means of the well-known formula $K = \frac{W \times 10^5}{L^3}$, where W = weight in grams, and L = standard length in millimeters. An increase in the value of K represents an improvement in the condition of the fish.

The results of this study of condition are summarized in Table VIII. In the main body of the table are presented the variations of K with change in length in each age group. At the bottom of the

TABLE VIII

COEFFICIENT OF CONDITION, *K*, OF THE LAKE ERIE SHEEPSHEAD ACCORDING TO AGE AND LENGTH, WITH SEXES COMBINED

The numbers of specimens are shown in parentheses.

Length group, in mm.	Age group								Grand average
	I	II	III	IV	V	VI	VII	VIII	
120–139	2.25 (6)	...	...	...	...	...	...	...	2.25 (6)
140–159	2.09 (77)	...	...	...	...	...	...	...	2.09 (77)
160–179	2.10 (222)	2.18 (2)	...	...	...	...	...	...	2.10 (224)
180–199	2.09 (81)	2.00 (15)	...	...	...	...	...	...	2.08 (96)
200–219	2.09 (6)	2.19 (42)	2.03 (1)	...	...	...	...	...	2.18 (49)
220–239	...	2.09 (18)	2.21 (13)	...	...	...	...	...	2.14 (31)
240–259	...	1.81 (1)	2.11 (8)	2.17 (4)	2.19 (4)	...	...	...	2.12 (17)
260–279	...	...	2.13 (3)	2.20 (5)	2.29 (5)	...	...	...	2.22 (13)
280–299	...	...	...	2.26 (5)	2.22 (11)	2.43 (4)	2.17 (1)	...	2.27 (21)
300–319	...	...	...	...	2.22 (8)	2.27 (6)	2.40 (5)	2.41 (2)	2.30 (21)
320–339	...	...	...	...	2.18 (3)	2.34 (8)	2.35 (7)	2.52 (4)	2.35 (22)
340–359	...	...	...	...	2.23 (1)	2.29 (11)	2.42 (7)	2.34 (3)	2.34 (22)
360–379	...	...	...	...	...	2.24 (4)	2.38 (4)	2.62 (16)	2.52 (24)
380–399	...	...	...	...	...	2.43 (1)	...	2.41 (4)	2.41 (5)
400–419	...	...	...	...	...	...	...	2.57 (1)	2.57 (1)
420–439	...	...	...	...	...	...	...	2.78 (1)	2.78 (1)
Grand average	2.08 (392)	2.10 (78)	2.16 (25)	2.21 (14)	2.22 (32)	2.32 (34)	2.38 (24)	2.54 (31)	2.16 (630)

table may be found the average of K for each age group, and in the column at the extreme right the variations of K with change in length, all ages combined. The grand averages at the bottom of the table indicate that the value of K increases progressively with each older age group. Apparently the oldest sheepshead of the samples were in the best condition. The values of K in fish of a single size group (body of table) show perhaps an even stronger tendency, although not a more consistent one, to increase with the age of the fish.

Since the successively older fish of a single size group are the slower-growing ones of that group, the possibility is suggested that slow growth may be correlated with a high value of the coefficient of condition. Such a correlation was found to exist in the Lake Superior longjaw. However, if growth rate and condition are correlated in the sheepshead, it should also be true that the values of K decrease progressively with an increase in the length of the fish in any single age group. The data (body of table) do not show such a decrease. Consequently, it cannot be said, on the basis of the data now available, that growth rate and condition are correlated in the sheepshead. It is possible, however, that such a relationship may actually exist, but that its presence is obscured by the combination of the sexes in the samples. It is not known to what extent the sexes differ in growth rate and condition. Since in many species of fish the coefficient of condition is higher in the females than in the males, it is possible that the absence of a consistent trend is due to differences in the sex ratios in the various averages. The only safe conclusion that may be drawn from the data available at present is that the condition of the sheepshead improves with age.

The grand averages in the column at the extreme right of Table VIII reveal a general tendency of the values of K to increase in the larger fish. Noticeable changes may be observed at lengths of 200, 260, and 360 millimeters. These changes, however, are associated with a shift in the age groups that dominate the different averages rather than in the size of the fish. These averages, then, show the change with the age, not with the size, of the sheepshead. The high average value of the coefficient of condition (2.16) indicates that the sheepshead belongs to a group with a rather heavy body form.

VII. SUMMARY

1. This study was based on sheepshead (*Aplodinotus grunniens* Rafinesque) taken from Lake Erie by means of trap nets and gill nets. The data on length–weight relationship were based on 2,183 fish, and those on age and growth on 784, all of which were taken at Vermilion, Ohio, and Sandusky, Ohio, during the period August 17 — November 21, 1927. The 1,570 sheepshead employed for the study of total length–standard length relationship were collected at several ports in 1927 and 1928.

2. The Lake Erie population of sheepshead consisted of age groups 0–VIII as represented in the collections. Age group I (year class 1926) predominated, comprising 56.2 per cent of the combined samples. The oldest and largest specimen collected was in at least its seventeenth year, measured 576 millimeters in standard length (about 27.2 inches total length), and weighed 7 pounds 14 ounces.

3. Length frequencies exhibited distinct modes at 105 and 170 millimeters only.

4. Considerable variation occurred in the growth of the different year classes.

5. The sheepshead grows most rapidly in length during the first year of life, when about 27 per cent of the length reached in the eighth year is completed.

6. The annual increment of growth in weight increases progressively during at least the first nine years of life, which indicates that sheepshead of this age with an average weight of $2\frac{3}{4}$ pounds are still in the midst of a fast-growing period of life so far as weight is concerned. Only 2 per cent of the total growth in weight attained in the ninth year is completed in the first year of life.

7. The "law of growth compensation" applies to the Lake Erie sheepshead.

8. A curve is presented that shows the relationship between the length and weight of sheepshead of different sizes. The curve facilitates the conversion of standard lengths in millimeters to total lengths in inches and vice versa, and of weight in grams to weight in ounces and vice versa. A table is provided in which the total lengths of sheepshead from 1 to 20 inches long are converted to standard lengths in millimeters.

9. The total length–standard length ratios decrease progressively

with an increase in the length of the fish, in contrast to the results found for several other species of Great Lakes fish, for all sizes of which a single conversion factor could be employed.

10. The coefficient of condition, K, increased progressively with the age of the sheepshead. It could not be established from the data available that slow growth was correlated with a high value of K. The high average value of K (2.16) indicates that the sheepshead is a heavy-bodied form.

U. S. Bureau of Fisheries
Ann Arbor, Michigan

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